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THE CONSTRUCTION OF ELECTRO-MAGNETS.

By TH. DU MONCEL.

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III.

VIII.—CONDITIONS GOVERNING THE CONSTRUCTION OF ELECTRO-MAGNETS.

The calculation of the elementary parts of electro-magnets is not all that is necessary. To secure the best results, it is also necessary to take into consideration the secondary causes which can influence them and their sources of action.

This question will now be considered, and will recall the conclusions reached by the writer, from numerous experiments tried during the past twenty years.

1*st. Conditions of electro-magnetic force which are dependent upon exterior causes.*—Descartes and many later physicists have shown that if a mass of iron be brought in contact with one pole of a bar magnet, that the attractive force of the other pole is augmented, and that the increase is somewhat proportioned to the mass. M. Dub, who wished to include a statement of this fact in the laws of electro-magnetism, considers that this increase is a result of the general law, that the force increases with the increase of length of the magnetic core. But this increase should by the law be proportioned only to the square roots of the lengths; whereas, according to the author's experiments, the increase is enormously greater, since the force is frequently more than trebled. Furthermore, the writer has shown that this increase is produced by iron masses of all shapes, some of which do not increase the length of the magnet to a notable extent, and also when not in immediate contact with the magnet proper. It has been observed during these experiments that the development of a magnetic surface has much to do with the phenomena. Now, the author's conclusion is, that the increase of energy is due principally to the effects of magnetic condensation developed by the contact of the two pieces, and that the stimulation of the free pole is a secondary effect, since the two polarities of any magnet bear a constant relation to each other.

This conclusion has been experimentally verified by alternately placing upon a long, soft, iron rod helices of different lengths but composed of the same lengths of wire. The helix which covers the entire rod is the one affording the least attractive force, although it has the greatest number of turns of wire. The helix which has the maximum effect is that which covers only one-third of the length, measured from the active pole.

Now, when these same helices are ap-

plied to iron rods of the same length as themselves, the effect is altogether different. Then the force increases as the length increases, but not in proportion to the length. The forces seem to increase in an arithmetical proportion, while the lengths are in geometrical ratio; and the rate of this increase seems to bear a direct relation to the number of cells of the battery. Only these last results will be here specified as applying to a particular case.

The effects about to be cited illustrate the action of electro-magnets when charged with a single helix upon one of the branches only, a kind upon which the author was the first to experiment, and which he calls *electro-aimants boiteux* (lame or crippled magnets), and which are nearly as energetic for the number of coils of wire as the magnets of two helices.

2*d*. *Relations of the electro-magnetic force to the form and disposition of the armatures.*—The author sums up his conclusions from his experiments in the following manner:

(*a*). The attractive force of electro-magnets, whether great or small, is greatest when that surface of the armature which is directly acted upon is most developed, and when the mass of iron exposed to the magnetic influence is most completely subjected to the magnetic forces.

(*b*). It results from this that the attraction of electro-magnets of two branches for flat prismatic armatures is greatest when the armatures are presented flatwise, if at a little distance from the magnet, while the converse is true for the condition of contact, and the greatest force is manifested when the armature is presented edgewise. For the attraction at a distance the ratio of the effects of the two positions may be as 59 to 92.

(*c*). The arrangement by which the armature is caused to rotate about a pivot near one of the poles is better than that by which it is allowed to move parallel to the line joining the two poles, as when it is made a cross-bar at the end of a tilting lever. The advantage of the former method is especially manifested in the case of magnets with a helix on one pole only, in which the forces developed under the two methods are in the ratio of 125 to 64.

(*d*). Prismatic armatures are attracted with a force proportioned to their extent of surface; but the *form* of the surface has a great influence, as the mean distance of the whole surface from the poles may vary considerably with the shape. Thus a cylindrical armature is attracted with much less force than one of prismatic form having the same amount of surface; the ratio of the forces being as 44 to 85.

(*e*). By reason of an analogous reaction to this last, the *lateral* attraction of electro-magnets, where the cores project a little way from the helix, is much less energetic than the attraction in the direction of the axis of the cores; the ratio being about as 18 to 33.

(*f*). Armatures made of permanent magnets aid the attraction only when used at a distance from the poles, and are kept parallel to a line joining the two poles. For other positions they are a disadvantage, as magnetic action, when exerted upon steel, is much less than upon iron.

(*g*). The attractive force due to the momentary closing of a circuit is, for any given distance of the armature, much greater than that arising from the constant action of the same current when a counter force is opposed to it. This fact may be referred to the effects of living forces, and to the polarization in the cell. The ratio of attractive forces is as 136 to 95.

(*h*). When the force of an electro-magnet is divided among several armatures, the total attractive force is augmented, but the force exerted upon any one armature is less in proportion as the number is greater. This increase of total force, however, is manifested only within certain limits, which are reached when the mass of the armatures is equal to that of the electro-magnets.

(*i*). The attractive force between an electro-magnet and an armature which has not been previously employed, is for a given current much greater than for the same magnet and armature, when they have been once subjected to the current. And to obtain a force nearly equal to that primarily produced it is necessary to reverse the current; but the maximum force exists only at the first closing of the circuit.

(*j*). The attraction of electro-magnets

at a distance is weakened when from any cause the first closing of the circuit has not been followed by the complete attraction of the armature. This is due, as in the preceding case, to the effect of residual magnetism.

(*k*). The repellant force exerted by electro-magnets upon magnetized armatures is far from corresponding with the attractive force which is produced by reversing the poles of the magnet. This fact, which was observed in the early experiments upon electro-magnetism, and which was for a long time discussed by Mussembroeck and Abbe Nollet, is easily explained as an example of induction by the magnet, which tends to develop upon the armature a polarity opposite to that which exists in the magnet. Now, in attracting, the action of the induction is to increase the dynamic effect, while in repulsion it diminishes it. (*Etudes du Magnetisme*, p. 103.)

(*l*). When the iron core of an electro-magnet extends beyond the helix the force is diminished; but if the poles be fitted with extension pieces in the inter-polar space, the force is augmented, and the maximum effect is reached when the space separating the auxilliary pieces is about one-fourth of the entire interval. This increase follows from the increase in the attractive surface of the poles, which then correspond to an armature.

(*m*). According to the experiments of M. Dub, the best condition of electro-magnets relating to the dimensions of their armatures are obtained when the different parts (separate branches, armature and bottom bar) are equal.

(*n*). This conclusion is naturally subordinate to conditions of application; for it is certain that if we desire prompt action in the armature, that it must be light; but we can then supply the deficiency of weight by reinforcing the poles of the magnet as above described.

3d. Conditions depending on the mass of the iron core.—The conditions of magnetic force depending on the diameter of the magnet and the degree of saturation may, under certain circumstances, be quite antagonistic; for though we gain force by increasing the diameter of the core, we may be subjected to loss because, by reason of size, the core is not charged to saturation, and then the central inert portion becomes, by a secondary action, like another armature. It has been attempted to obviate this difficulty by employing tubular magnets, which allow of easy magnetizing and demagnetizing; but it was found that there was a loss of force by this system, and which led to their rejection for a time. The author in 1862 began to study the conditions of force in this kind of magnet, and after many experiments presented a memoir to the *Académie des Sciences* containing the following conclusions:

(*a*). The greater force of electro-mag nets with solid cores is not in consequence of their greater weight, but depends chiefly upon the disposition of their polar surfaces with reference to their armatures.

(*b*). If the polar extremity of a tubular magnet is furnished on the inside with a plug, which may be very thin, the force is very nearly the same as when the core is solid. But no such result is realized if the pole be augmented by a ring of iron outside the tube; which proves that it is not so much the increased amount of polar surface that reacts upon the attractive force as the disposition of this surface.

(*c*). If we consider in the case of the ring, that the latter acts as an armature, and that such action is prejudicial to the attractive force by disseminating it, as in the case of the magnet with several armatures; and that in the case of the plug or stopper there is a concentration of magnetic forces from different sides of the tube we can see why there should be a considerable difference of energy in the two cases; and we can readily estimate the result of the magnetic concentration in the second case if we suppose the plug projected upon the outside of the tube at the moment the latter is magnetized.

(*d*). It results from these effects that, to employ tubular electro-magnets with good effect, we ought to furnish their polar extremities with plugs whose thickness is at least equal to that of the tube. We may obtain an increase of force which in telegraphic magnets will be in the ratio of 25 to 38.

The thickness of the tube should bear proper relation to the strength of the current which excites the magnet. The experiments of Hughes upon telegraphic instruments led him to the conclusion

that this thickness should be one-fourth the diameter. But the author's experiments led him to conclude that for electro-magnets of large size the thickness may be reduced below this proportion, and in a previous memoir the problem was treated at length,* where it was shown that

$$c'=c\sqrt[3]{\frac{x^3}{4(x-1)}},$$

in which c' represents the diameter of the tube; c the diameter of a solid iron core capable of saturation; x the divisor of c' to give the thickness. This value of x may without great inconvenience be made as high as 7.

(*e*). The inconvenience of solid magnets arises from residual magnetism and of magnetic condensation; but we can diminish considerably these effects by insulating magnetically the two branches from the bottom bar by copper discs, or by inserting in the bar itself a thickness of copper.

IX.—Relations which the Grouping of the Battery bear to the Circuit and to a given Electro-Magnet.

As it is a matter of importance that the electro-magnet should be properly adjusted to the current that charges it, it is, of course, equally important that the battery should be arranged with reference to producing the best effect upon a circuit containing a given magnet. Ohm has given a formula for such cases, which is found in all works on physics, but which is of limited application in practice—a fact which led the author in 1860 to seek for another method of analysis, based upon experimental grouping of the cells. The problem is to determine the most advantageous grouping of the elements of a battery to work against a known resistance. Thus, having a battery of 12 cells, it is required to know whether it will be best, in working against the resistance R, to arrange the cells in groups of 3 for quantity and 4 for tension, or in 6 groups of double elements, or 2 groups of sextuple elements, etc., etc.

Now, to determine the general formula, suppose the number of cells to be n. Let a be the number united for *tension* and b the number united for *quantity*. The expression for intensity of current, when r is the resistance in each cell and R the resistance of the circuit and E the electromotive force, is

$$I=\frac{E}{\frac{r}{b}+R}$$

for each group of b cups, and for the a groups united in tension

$$I'=\frac{aE}{\frac{ar}{b}+R} \text{ or } I'=\frac{abE}{ar+bR}.$$

Now, this formula, as well as that of Ohm, is susceptible of a maximum value, for as $ab=n$ and $b=\frac{n}{a}$ the equation becomes

$$I'=\frac{nE}{a+\frac{n}{a}R}=\frac{E}{\frac{ar}{n}+\frac{R}{a}}.$$

By considering a as the variable we find the maximum value corresponds to

$$\frac{r}{n}-\frac{R}{a^2}=0;\ \text{whence } a=\sqrt{\frac{nR}{r}},$$

and as $a=\frac{n}{b}$, $b=\sqrt{\frac{nr}{R}}$, or simply $\frac{n}{a}$.

This conclusion is easily reached without the aid of the differential calculus, as the author has previously shown in *Exposé des applicationes de l'Electricitie*, Vol. I.

Some important results are deduced from this condition of maximum value.

1st. When a battery is arranged for maximum value with reference to a given external resistance R; this resistance is equal to that of the battery, and from the equation

$$a=\sqrt{\frac{nR}{r}} \text{ we get } R=\frac{a}{b}r,$$

and the right hand member of this equation represents the resistance of the battery.

2d. The most advantageous grouping of a battery for a given intensity, I, may be also determined, provided the resistance R is not greater than nr, as under maximum conditions we have

$$\frac{nE}{ar+bR}=\frac{nE}{2ar}=\frac{nE}{2br}$$

whence we get

* Recherches sur les meilleures conditions de construction des Electro-Armants.

$$a=\frac{2IR}{E} \text{ and } b=\frac{2Ir}{E};$$

very convenient and simple formulas for use in applications of electricity.

In some papers presented by the author to the *Académie des Sciences* in June and August, 1860, and in September, 1869, he indicated the limits of external resistance against which it is advantageous to employ certain specified methods of grouping of the battery. These limits for b cells joined for quantity are $\frac{nr}{(b-1)b}$ and $\frac{nr}{(b+1)b}$; that is to say, for cells in pairs the limits of resistance R, will be $\frac{nr}{2}$ and $\frac{nr}{6}$. For triple grouping the limits are $\frac{nr}{6}$ and $\frac{nr}{12}$. For quadruple $\frac{nr}{12}$ and $\frac{nr}{20}$, etc., etc.; and it has also been shown that, as Ohm has proved that the resistances R corresponding to maxium effects for different arrangements of the battery, are represented by $\frac{nr}{b^2}$; that is to say by $\frac{nr}{4}$ for doubled cells, $\frac{nr}{9}$ for tripled, $\frac{nr}{16}$ for quadrupled, etc., etc. Finally it was demonstrated that the limits of resistance of the external circuit for which the grouping by twos, threes or fours compared with the joining for *intensity* and for *quantity*, furnishing the same current, correspond on the one hand to a half, third or fourth of the total resistance of the battery, and on the other to a half, third or fourth of the resistance of a sin gle cell.*

Thus we know by the preceding calculation that for a Daniell battery of 20 cells the resistances of the external circuit, which would require an arrangement of the cells in pairs, lie between 10,000 meters and 3333 meters of telegraph wire. If the resistances are between 3333^m and 1666^m, the cells may be in threes, and if between 1666^m and 1000^m we may adopt the quadruple arrangement.

It is seen from the foregoing that there is no difficulty in determining the best arrangement of any given number of cells to work against any given resistance, since it will suffice to divide the total resistance of the n cells successively by 4, 9, 16, etc., and see which quotient most nearly corresponds to the external resistance. The divisor then represents the square of the number of cells in each group. and the number of groups is obtained by dividing n by the number of cells thus grouped for quantity.

All these calculations are exceedingly simple, and it seems astonishing that so much time and money is expended in useless researches and trials, when the best conditions for useful effect are so easily determined.

Some exacting people assert that these calculations are only rigorously true when we get whole numbers for results, as we cannot divide a battery cell; but in electrical applications we are satisfied with approximate results. It is true we cannot divide the cell of a battery, and so we cannot always realize the maximum conditions; but the calculation affords us a means of determining what numbers to adopt in grouping to obtain the best result. Thus in the example in Chapter V. we found the value of $a = 3.074$; now it is evident that 3 groups in intensity are indicated, and as 8 divided by 3 gives 2.7, there should be 3 cells in each row.

The formulas presented in the preceding articles enable us to compare the forces of different electric generators. There are, however, in these calculations certain considerations which, not having been viewed in the same light by different physicists, have led to disagreements that are to be regretted. Thus, according to Jacobi, we may compare two batteries, both of which are working under maximum conditions; but for this purpose the exterior and interior re-

* These different deductions are obtained successively by equating the values of I obtained by supposing the different groupings of the battery and obtaining from them different values of R. The conditions of maximum value of I may be thus obtained without employing the calculus; for supposing b and b' the cells joined for quantity in two consecutive groupings, we find in equating the two expressions:

$$ar+bR=a'r+b'R$$

or $$R(b-b')=r\left(\frac{n}{b}-\frac{n}{b'}\right)$$

whence $$R=\frac{nr}{bb'}.$$

This may be transformed into

$$=R\frac{nr}{(b-1)b} \text{ or } R=\frac{nr}{(b+1)b}$$

according as we compare the groupings. But if we make $b=b'$ then $R=\frac{nr}{b^2}$ and we arrive at the maximum values previously obtained.

sistances for each case must be equal. The intensity of each would then be $\frac{n\mathrm{E}}{2ra}$ or $\frac{n\mathrm{E}}{2b\mathrm{R}}$. Now if for the battery taken as the standard of comparison, we assume $n=1$, which reduces the preceding formula to $\frac{\mathrm{E}}{2r}$; we have if we assume the intensities equal:

$$\frac{n\mathrm{E}}{2ar}=\frac{\mathrm{E}'}{2r'} \text{ and } \frac{n\mathrm{E}}{2br}=\frac{\mathrm{E}'}{2r'};$$

equations which may be put under the form,

$$\frac{b\mathrm{E}}{2r}=\frac{\mathrm{E}'}{2r'} \text{ and } \frac{a\mathrm{E}}{2\mathrm{R}}=\frac{\mathrm{E}'}{2r'},$$

and we can deduce the values of a and b by supposing the resistance R to the resistance r' of the cell of comparison. Then we have

$$a=\frac{\mathrm{E}'}{\mathrm{E}} \text{ and } b=\frac{\mathrm{E}'}{\mathrm{E}}\times\frac{r}{r'}$$

and the total number of elements is found by multiplying a by b.

Proceeding on this plan, we find that 5 Bunsen cells represent 9 Daniell cells, each with a surface 11 times as great; which indicates that we should employ 20 Daniel cells, conveniently arranged, as an equivalent for one Bunsen cell. It has been similarly found that 3 Bunsen cells equal in intensity 4 cells of the mercury sulphate battery, each of which had a surface three and a third times that of the Bunsen cell; which indicates that it would require 5 of the mercury sulphate cells to be equal to one Bunsen.

When this method of Jacobi has been duly considered, it is seen that he desired to avoid giving the exterior resistance R a determinate value; but in fact this resistance is represented in the resistance of the battery which is employed as a unit of comparison, and in the preceding example it is equal to 153 meters of telegraph wire. Now, it is easy to see that in proportion as the resistance increases or diminishes, the above figures are singularly modified; for the value of R may be reduced more or less or become more or less preponderant in the value of the denominator of the expression for intensity of current. It is this fact which excites the criticisms of many physicists, We could perhaps take for a starting point a value of R which would be a mean of the resistance of the different cells, but we should not have gained much, and this system of comparison would apply only to short circuits. In such a case we might begin by taking I equal to the intensity of the battery chosen as a standard of comparison, and then obtain the values a and b by the formulas $a=\frac{2\mathrm{IR}}{\mathrm{E}}$ and $b=\frac{2\mathrm{I}r}{\mathrm{E}}$, which in the case of the Bunsen and Daniell batteries will give for a resistance

$$\mathrm{R}=153^{\mathrm{m}},\ \mathrm{I}=36.55.$$

$$a=\frac{2\times 36.55\times 153}{5973}=1.87,$$

and

$$b=\frac{2\times 36.55\times 931}{5973}=11.4.$$

This brings us back to the conclusion previously reached, as R is the resistance of the battery used as a standard of comparison. Suppose R = 1000m, then I becomes equal to 9.64, a = 3.2, and b = 3, and we see that instead of employing 20 Daniell cells it will be necessary to use only 9 to obtain the equivalent of a Bunsen cell.

X.—Tables for Use in Calculations Relating to Electro-Magnets.

The following tables are believed to be indispensable to a work treating of calculations in electro-magnetism. It should be mentioned that by reason of the omission in Ohm's formula, of a term dependent on polarization effects, the figures representing the resistances of battery cells are too large, and as they increase with the resistances of the external circuit,* there are given in the first table values both for short circuits and for resistent circuits.

The first values were calculated by M. Ed. Becquerel; the second by the author; so that to obtain the best results it will be necessary to use the author's figures when the external resistances are great and Becquerel's when they are small.

* In taking into account the effect of polarization, the formulas for E and r according to Ohm's method are:

$$\mathrm{E}=\frac{\mathrm{I}'(\mathrm{R}'-\mathrm{R})+(\mathrm{I}e'-\mathrm{I}'e)}{\mathrm{I}-\mathrm{I}'} \text{ and } r=\frac{(\mathrm{I}'\mathrm{R}'-\mathrm{IR})-(e-e')}{\mathrm{I}-\mathrm{I}'}$$

which differ from the applied formulas only in the second terms of the numerators, which do not appear in the latter. This omission causes the calculated values to be greater than the quantities R and R'.

TABLE NO I.—VOLTAIC CONSTANTS.

Batteries in common use.	Electromotive force E.	Resistance r in meters		Ratio of electromotive force.
		Du Moncel.	Becquerel.	
Daniell battery (French telegraph pattern)....	5973	931	180	1.00
Bunsen's cell (amalgamated zinc).....	11123	153	57	1.86
Delaurier cell (chromic acid and salt solution)	12413	366	"	2.08
Chutaux cell (potassic bichromate).....	11400	600	"	1.91
Duchemin cell (ferric chloride and salt solution).....	9640	942	"	1.61
Marie Davy cell (mercuric sulphate and water).....	8192	550	"	1.37
Leclanché cell (large size).....	7529	400	"	1.26
De la Rues cell (fused silver chloride and zinc chloride; size, minute).....	5596	748	"	0.94
Prudhomme's cell (lead sulphate and water...	3301	880	225	0.55

The figures in Table No. 2, giving the values of the diameters of wire, with and without the silk covering, are not exactly the results obtained by direct measurement. These results are deduced from measurements with the rheostat upon manufactured electro-magnets, so that open spaces and other irregularities of winding are taken into account. This method is not very exact in one sense, but it is clear that it gives values much more serviceable for calculation, for it takes into account quantities which would otherwise be neglected.

These values are easily calculated from formula (5). When $a = 0.012$, $c = 0.012$ and $b = 0.12$

$$g^2 = f\sqrt{\frac{0.000000000289529}{H}}$$

and as $\frac{g}{f} = s$, s representing the diameter of the copper wire, measured directly without the silk,

$$f = \sqrt{\frac{0.00000000028952}{\frac{H}{s^2}}}$$

TABLE II.—DIMENSIONS OF WIRE USED FOR ELECTRO-MAGNETS.

	Gauge numbers.	Diam. naked wire.	Diam. covered wire.	Values of f.	f^2.	$\frac{s^2}{g^2}$	g^2.
		m.	m.				
Common gauge, silk covered.	No. 32	0.00014	0.00023	1.6428	2.6988	816.3	0.0000000529
	" 28	0.00022	0.00033	1.5000	2.2500	330.6	0.0000001089
	" 24	0 00027	0.00040	1.4814	2.1934	219.5	0.0000001600
	" 20	0.00035	0.00048	1.3714	1.8796	130.6	0.0000002304
	" 16	0.00040	0.00055	1.3750	1.8906	100.0	0.0000003025
	" 12	0.00049	0.00065	1.3265	1.7582	66 6	0.0000004225
	" P	0.00058	0.00077	1.3275	1.7609	47.5	0.0000005929
Decimal gauge, cotton covered.	No. 1	0.00060	0.00122	2.0333	4.1331	44.4	0.000001488
	" 2	0.00070	0.00134	1.9143	3.6634	32.6	0.000001795
	" 3	0.00080	0.00146	1.8250	3.3306	25.0	0.000002132
	" 4	0.00090	0.00158	1.7555	3.0800	19.8	0.000002396
	" 5	0.00100	0.00172	1.7200	2.9584	16.0	0.000002958
	" 6	0.00110	0.00184	1.6727	2.7989	13.2	0.000003385
	" 7	0.00120	0.00196	1.6333	2.6687	11.1	0.000003842
	" 8	0.00130	0.00208	1.6000	2.5600	9.4	0.000004326
	" 9	0.00140	0.00220	1.5714	2.4670	8.2	0.000004840
	" 10	0.00150	0.00232	1.5466	2.3901	7.1	0.000005382
	" 11	0.00170	0.00254	1.4941	2.2320	5.5	0.000006451
	" 12	0.00180	0.00266	1.4777	2.1844	4.9	0.000007075
	" 13	0.00200	0.00288	1.4444	2.0851	4.0	0.000008294
	" 14	0.00210	0.00300	1.4285	2.0392	3.6	0 000009000
	" 15	0.00235	0.00327	1.3915	1.9349	2.9	0.000010690
	" 16	0.00260	0.00354	1.3615	1.8533	2.4	0.000012532

TABLE No. III.—DIMENSIONS OF WIRE IN COMMON USE.

Old Gauge	Diameter uncovered.	Meters per kilogram.	Diameter covered wire.	Meters per kilogram.	Resistance per kilogram.
No.	m	m	m		
12	0.00056	514	0.00054	515	—
14	0.00050	680	0.00048	673	—
16	0.00044	796	0.00044	780	22.30
18	0.00040	867	0.00040	929	29.60
20	0.00036	1238	0.00034	1390	31.47
22	0.00032	1439	0.00032	1420	—
24	0.00028	1925	0.00028	1872	43.75
26	0.00026	2389	0.00026	2257	138.23
28	0.00024	2854	0.00022	3230	174 94
29	0.00023	3054	0. —	—	185.77
30	0.00021	3822	0.00020	3920	228.46
31	0.00020	4042	0.00019	4390	471.51
32	0.000185	5875	0.00017	4810	528.57
33	0.00017	6130	0 00015	9400	967.56
34	0.00016	7750	0.00 14	9580	—
38	0 000125	10550	0.000125	9650	1680
39	0 000115	11950	0.000115	10600	—
40	0.00010	18400	0.00009	16290	—
42	0.00008	24800	—	—	4228
43	0.000075	25600	0.00007	26310	—
44	0.00006	36500	0.00006	35400	17500

TABLE No. IV.—DIMENSIONS OF WIRE IN COMMON USE.

Decimal Gauge.	Meters per kilogram.	Diameters.	Decimal Gauge.	Meters per kilogram.	Diameters.
No.			No.		
P	670	0.0005	10	70	0.0015
1	418	0.0006	11	66	0.0016
2	330	0.0007	12	54	0.0018
3	208	0.0008	13	40	0.0020
4	180	0.0009	14	34	0.0022
5	160	0.0010	15	30	0.0024
6	137	0.0011	16	26	0.0027
7	100	0.0012	17	19	0.0030
8	85	0.0013	18	16	0.0034
9	75	0.0014	20	10	0.0044

Tables 3 and 4 have been prepared with much care by M. Bonis, a manufacturer of wire in Paris, who uses copper whose conductivity is 94 to 96.

The covered wire is smaller than the wire before covering, because of the tension to which they are subjected in the covering process, which causes a reduction in diameter averaging three hundredths of a millimeter. So that there is an increased length per kilogram for some of the sizes.

In the preceding tables the resistances are given in meters of telegraph wire. These are reduced to *ohms* by dividing by 100.

The values of electromotive force in Table 1 may be reduced to *volts* by multiplying by 1.079.

TABLE No. V.—RESISTANCES.

Diameter millimeters.	Gauge.	Meters per kilogram.	Resistances Ohms. per kilogram.	Resistances. Ohms. per kilometer.
	Old gauge.			
0.02	—	355584	1803084	52317
0.10	40	14369	30377	2113
0.20	31	3614	1923	531
0.30	23	1607	378	235
0.40	18	902	119	133
	Decimal gauge.			
0.50	14	576	49	85
0.60	1	401	24	59
0.70	2	294	13	43
0.80	3	226	7.5	33
0.90	4	178	4.6	26
1.00	5	144	3.0	21
1.50	10	64	0.59	9.2
2.00	13	36	0 19	5.3
2.50	15	23	0.078	3.39
3.00	17	16	0.037	2.36
3.50	18	12	0 020	1.72
4.00	—	9	0.011	1.32
4.50	20	7	0.0074	1.04
5.00	—	5.76	0.0049	0.84
5.50	—	4.71	0.0033	0.70

AT a recent meeting of the Physical Society Dr. Jas. Moser read a paper on "A General Method of Strengthening Telephonic Currents." This consists in forming a primary circuit of the telephone transmitter or derived circuit, a set of induction bobbins in derived circuit, and a charged secondary battery, the whole circuit having a very low resistance. Each primary bobbin has a secondary wound over it, and these secondaries are connected in quantity to the telephone line, which has at its remote end a set of telephones in derived circuit to the earth or return wire. In this way one line wire serves to supply a large number of separate telephones, a hundred being employed by Dr. Moser to transmit music from the Hippodrome in Paris to the Place Vendôme. The system is applicable to long lines; and the induction noises are reduced by subdivision among the separate telephones.

THE SUEZ CANAL AND THE EUPHRATES VALLEY RAILWAY.

"The Nautical Magazine."

REMOVING a neighbor's landmark is numbered among the nine special sins denounced in our very charitable Commination Service, and no few honest thinkers, puzzled to explain the existence of somewhat similar sentiments in the Bible itself, have gone so far as to assert that allusion is made to achievements like the Suez and Panama Canals, which certainly do alter the natural face of the land, and completely obliterate our neighbor's landmarks. There assuredly is something approaching the impious in the French suggestion to turn the lower levels of the desert into a vast inland sea, while the notion of converting South America into an island proves equally unseemly in certain quarters. But pessimists of this school evidently belong to a class akin to those "stay-where-you-are" politicians of a former day, who for similar reasons first denounced roads into an enemy's country, and subsequently raised a hue and cry against railways. Happily most likely for the world, science takes no notice of these perennial croakings, nor of the constant attempts made by bigotry to enslave her. Having grown accustomed to them from long acquaintance she heeds them not in the slightest, pursuing unabated the even tenor of her course towards perfection. Those who love progress and those who do not must accept matters as they are, and expect in the future still greater effacements of existing geographical distinctions. Nevertheless it must be conceded in fairness that each mundane alteration made in Dame Nature's map is the occasion for strife among the nations, and it is too much to hope that the Suez Canal will escape the hateful fate which for some occult reason has dogged the steps of science throughout all ages. M. de Lesseps' handiwork has become a new bone of contention which it seems likely may be fought for by the European nations with even more bitterness than Gibraltar ever was in the past. Already it has led to the shedding of blood, although by a happy diplomatic fiction we are not supposed to be at war with any one, and before the century closes it may, probably will, lead to fresh and important changes in the geography of Europe. Moreover, and what is equally consequential from our point of view, it may bring around considerable alterations in the respective commercial positions of the leading European Powers. It is this problem we desire first to consider.

Those States who have an outlet on the Mediterranean Sea are now several days nearer the East than ourselves, and by right of that newly-gained advantage possess a *natural* trade interest in India and China at least equal, if not superior, to our own. Since Count Ferdinand de Lesseps' waterway was opened, France, Italy, Austria, and Russia, have alike paid growing attention to Eastern affairs. One and all have started direct steamship communication with various ports in the Orient; each, it appears, is daily adding to its mercantile fleet; nor does it seem unreasonable to anticipate that as time grows older these great nations, and possibly Spain and Greece also, will increasingly supply their own shipping wants in the East, instead of largely employing British bottoms as now. In each country a revolution has commenced in favor of home service, and if the Suez Canal remains permanently open, we shall doubtless see constant large additions made to their Mercantile Marines with comparative stagnation at home. Not that the British shipping engaged in the Occidental and Oriental trades is likely to show any signs of diminution—far otherwise. Commerce is rapidly growing between England and India, and between England and Australia; nor is there any pressing danger of a decline in our trade with China. Our commerce with the Eastern world is bound to grow apace, so long as we maintain the integrity of our world-wide Empire; but whereas the annual augmentations to our mercantile fleet will be gradually progressive, the

additions made to those of foreign nations will, for some time to come at least, be by leaps and bounds. To otherwise put it—our excessive preponderance will steadily pass away. Any one who has closely followed the fortunes of the Messageries Maritimes, Rubattino and Austrian Lloyds lines during the past few years will know that these pessimist forebodings are not absolutely uncalled for. Even Russia, with a capital overland route to China, has found it worth her while to start a direct line of steamers between Odessa and Hankow, threatening our tea ships with the loss of a most lucrative branch of transport. Let optimists say what they like, there is, unhappily, only too much reason for our misgivings, and this every one may observe for himself by glancing over the files of that well-compiled Parisian shipping journal, *L'Indicateur Maritime Universel*, which gives particulars of the chief mercantile fleets of every nation engaged in the foreign trade. In its columns we can trace the progressive history of each company. Those who have not noted the doings of the Messageries Maritimes and Rubattino Companies will find therein ample matter for quiet reflection, possibly of a not over pleasant character. Until the Suez Canal was dug neither of these Companies had a vessel employed in the Eastern trade; to-day both possess fleets of considerable magnitude, to which additions are being made, so to say, daily. Can this revolution be deemed advantageous to England? We fear not, despite the glee evidently felt by certain daily journals at this country owning four-fifths of the shipping passing Suez. So far as we can see there is little significance in the fact, and that little, if either way, counts against us. It certainly affords no occasion for rejoicing, or for the singing of triumphal pæans, as until the opening of the Canal, and while commerce had to round the Cape, English steamers were alone seen in Eastern waters. Twelve years ago neither France, Italy, Austria, nor Russia ran a single steamer between the Mediterranean and the Indian Ocean; whereas now the vessels of their steam fleets are both numerous and powerful. Why this should be regarded as a triumph of British enterprise we confess our inability to see, for, had not the Suez route been opened, it is very doubtful whether a single foreign steamer would yet have found its way to Bombay, Point de Galle, Singapore, or Hong Kong.

Unquestionably the chief feature in the near future will consist in the revivification of French commerce with the East. Possessing a magnificent seaboard, with several good harbors along the Mediterranean, and an almost complete railway system, our enterprising neighbors are sure to avail themselves to the very utmost of their splendid good fortune. Being many days' passage nearer Port Said than the nearest English ports, namely, Plymouth or Southampton, and having as well at command unusual facilities for inland communication, they would be the next thing to insane to continue sending goods to England for transhipment, or to further employ British shipping in the traffic between Bombay and Port Said. Trade between France and the East is much larger than is generally supposed, incomparably larger than is revealed by any *prima facie* examination of trade statistics. From China alone the French import annually several million pounds worth of raw silk, but a portion only of this commerce is entered in their Board of Trade returns. Considerable quantities are still shipped in English bottoms, despite the fact that nine-tenths of the silk factories are located in the south, mostly around Lyons. Northern France still obtains via England a material proportion of such Oriental wares as she consumes—a negation of common sense and all economic laws of distribution that must find a speedy ending, now that French shipowners are learning to appreciate the general advantages accruing to Marseilles through its central position. Is it reasonable to suppose that Parisians will wait a week or more for goods to travel to England first, when a few hours' railway ride will carry them from Marseilles to Paris? The world is not quite so mad as all this, and Frenchmen above all people are qualified to take care of their own interests, whether commercial or political. That our trade has not been cut to pieces already is solely due to the intense selfishness; to the unutterable short sightedness and folly of the French railway companies, who have never afforded merchants the least encourage-

ment. To their prohibitory charges, more than to anything else, we owe the continuance of our maritime supremacy; but signs are not wanting to tell us that, although somewhat late in the day, these unpatriotic bodies are at length beginning to understand in what direction lies their best hope of future prosperity. By lowering freights they are now seeking to divert French commerce with the East to the Marseilles route, and according to a recent statement, their efforts are meeting with a fair measure of success.

Probably enough this change of policy on the part of the Great Southern of France, the Paris and Lyons, and other railways is due to no more exalted motives than self-protection. By the opening of the St. Gothard tunnel a new route has been opened for goods to reach western France, and it may be that this threatened competition has led the French companies to reconsider their position. The same cause is unquestionably diverting traffic to the Antwerp route, and is also likely enough to affect French railways in the direction suggested. Moreover, the Arlberg tunnel is rapidly drawing to completion. When it is opened (which will be at no very distant date) both the west and north of France are bound to be extensively supplied through Lombardy and Switzerland, and to counteract this new competition we may rely upon it that freights for merchandise and passengers will be again reduced on all the lines connecting Marseilles with Lyons, Dijon, and Paris.

Each reduction in charges made by these railway companies will lead to an increase in the Mercantile Marines of France, Austria, and Italy, and add to the importance of Port Said and Suez in the eyes of all European nations. Already, commerce between the East and West has been largely diverted from its ancient route round the Cape of Good Hope, and, through the rapid supercession of sailing vessels by the colossal high-speeded steamers of this era, seems destined to desert it almost entirely; especially, if it looks probable, railway freights on the Continent are generally lowered. Time is a factor that has to be allowed for when solving any trade problem, and granting that the companies reduce their tariffs so as to compete with English shipowners, and work in concert with the steamship lines managed by their countrymen, the world will witness another great trade revolution from which English shipping interests will seriously suffer.

In the event of M. de Lesseps' Canal being permanently kept open and maintaining its present position as England's road to India, there can be no doubt but that a large and increasing share of prosperity will fall to the lot of Marseilles, Genoa, Venice, Trieste, Brindisi, and other Mediterranean ports; indeed, one or more of them in time is likely to rival Liverpool or Glasgow in commercial grandeur; possibly may far surpass either of those great shipping centers. Having Western Europe, with its enormous population, as a market for the products of the Orient, and *vice versa* having the entire East to supply with the manufactures of Europe, there seems no positive counter reason why the more fortunate and flourishing amongst the southern outlets should not ultimately grow as rich, as well populated, and as important as Berlin, Brussels, or Paris; or, for the matter of that, as vast as London itself. At present, of course, it would be mere waste of energy to attempt to prophecy which towns will fall upon evil days and languish away into insignificance, or which will leave their indelible marks upon the pages of history, civilization and commerce. Such rises and such decadences are almost entirely dependent upon national enterprise and the idiosyncracies of trade; nevertheless, it requires no Merlin-like gifts to see that Venice and Genoa will again emulate their glorious past, or that Marseilles, Trieste, Brindisi, and Salonica, will be numbered among the great cities of the future.

One point, however, must not be overlooked in any inquiry into the commerce or strategic influence of the Suez Canal. It is ever liable to be seized by some one of the Great Powers and closed to commerce for a time—perhaps for months or years should England and France again come to blows. Both have important interests in the East to defend, equally to be attacked; and as of old the battle for supremacy would be partly fought out in the Indian and Chinese Seas. In that

eventuality the nation obtaining the Suez Canal would reap an immeasurable advantage. Indeed, its possession would half win the battle. Neutralization is proposed under the joint guardianship of that sublimely impotent mental creation, the European Concert. But all efforts in this direction must prove futile, mere vanities of vanities, as in times of war treaties and conventions are very apt to go the way of all flesh. France and Italy, if not several other of the Powers, favor the neutrality proposition, probably foreseeing that sooner or later it may operate to embarrass England's military action, while strange to say not a few shipowners in this country are numbered among its adherents. However, it is very doubtful whether the latter have given any deep consideration to the problem, for if they had they would probably have found out by this time that the suggestion is chimerical to a degree. As the *Temps* very properly points out, there is something childish about the scheme from beginning to end. Seeing that in one day England seized the canal along its whole length, while unprepared Europe looked on in amazement, it is mere waste of breath to talk about securing by a European Convention its free passage for ships of commerce. Moreover, it is impossible that English diplomacy can be beguiled by so flimsy a pretense. Every statesman in this country understands that the foreign cry for neutrality is only a fresh attempt on the part of Europe to stay the hand of England and cripple her future power for good or evil in Asia. Besides, if any such Convention was signed at all, reservations about *force majeure* would necessarily have to be inserted, and this plea can always be put forward to countenance military operations undertaken contrary to the spirit, if not to the letter, of international compacts. No belligerent can conscientiously carry out its engagements with other nations. Circumstances are always arising for which no previous provision was or could have been made, and, besides, when the war path is being trod military necessities are paramount to all other considerations. Let England be at war with France, Italy, Russia, or any Power, and no Convention would prevent them trying to aim a vital blow at her in the plains of the Egyptian Delta. The instrument would then become a mere piece of waste paper. So long as the waterway between Port Said and Suez continues as now to be England's highway to the East, so long will Egypt be her battle-field, and if in time of war she does not herself seize the Canal other nations will.

In the next place the Egyptian race is liable to "kick against the pricks;" in other words, to rebel against the European control, and at no time more likely than when we are involved in an imbroglio with one of the Mediterranean Powers. At any moment a popular movement might end in dethroning the reigning Khedive and in the seizure of the Canal. Treachery is always to be feared when dealing with Asiatic races, and unfortunately for us unfriendly counsels are often tendered to them by our disguised foes. If left undefended as now, the Canal could be seized and closed against us long before we received notice of any such intention, while supposing that at the same time our relations were greatly strained with France or Italy, a flying expedition emerging from Toulon or any other great naval dockyard on the Mediterranean, might cross unperceived to Port Said and succesfully bar our road. The only ways to guard against this prospective danger are to double our Mediterranean fleet, to convert Cyprus into a place of arms, and to employ a large number of cruisers in these waters; or to construct an alternative route, and render ourselves somewhat independent of the modern Gibraltar.

Neutralizing the Canal will not safeguard our interests in the least; it will only bring us into graver dangers and hasten the day when its possession will be fought for among the European lions. Nor do the patrons of the scheme seem themselves to have any distinct notion as to what the word means or how their plan is to be put into operation. In what possible way can the Canal be neutralized? It certainly is not proposed to prohibit the passage of ships of war during times of peace. If so, Europe might as well surrender Asia to the Asiatics. In these days of superlative weapons every European in Asia might be massacred long before aid could arrive round the Cape. No nation, least of all

England, would consent to forego the advantage of rapid communication between the different sections of its Empire, while in times of war it is quite certain the provisions of any agreement would be disregarded by the belligerents. If France was at war with England her military policy would be inevitably directed to blocking the Canal against us, while her emissaries stirred up insurrection in India. The only possible result of a European convention with regard to the passage of the Canal would be to lull us into a sleep of false security, out of which we might be rudely awakened when too late.

Sir William Andrew and many other Anglo-Indian authorities throw forward as a remedy the construction of a railway through the Euphrates Valley, from Alexandretta in the Bay of Iskenderoon, to Grain at the head of the Persian Gulf; and I take it as assured that among the more important outcomes of passing events in Egypt will be the construction of that railway under State guarantee, or something very much akin to a guarantee. The distance between the two places above mentioned is estimated at about 920 miles, and as the line would traverse a flat country devoid of any serious engineering difficulties the capital required would be comparatively small. Knowing at what price railways have been laid in America and India the estimate of £7,500 a mile does not seemingly err on the side of minimisation. At this rate a capital of about eight millions would suffice to construct the line, including stations and plant, and upon this sum dividend earning should not be impossible. In the worst case a guarantee of 4 per cent. interest would only cost Government the inconsiderable sum of £320,000 per annum, compared with which the political advantages to be obtained are immeasurably more consequential; indeed, cannot be weighed in the same balance. Besides which, the saving of seven days in the passage to India, would enable Government to effect several economies in administration, and in all probability to more than save the actual outlay. About the strategic advantage of a quick alternative route which would make us to some extent independent of the Canal there can be no two questions. It would enable us to govern India twice as efficiently and ten times more safely than at present, while it would do more than anything else to secure the peace of Europe. Egypt and the Suez Canal would then lose much of their political significance, and it might be possible for Continental nations—then no longer jealous of England—to come to look upon the Canal in the light of a commercial waterway only. Of course, we should take upon ourselves the material as well as the moral protection of Turkey in Asia, and this would mean fighting the Sultan's battles for him. This, however, might be to our advantage. It would secure the independence of the Turkish Empire and seriously check, if not put an end to Russian encroachments in that quarter.

The moment peace is assured in the Delta, and friendly relations are again set up with the wily Sultan, negotiations it is to be hoped will be opened up with a view to obtaining the indispensable concession from the sovereign ruler of Syria and Mesopotamia. If already in train they will have been commenced not one moment too soon. France has ever studied to exercise an influence in Syria, and if French capital or French enterprise is directed to this undertaking, we shall at some future day experience just the same trouble that we are now undergoing at Suez. Syria must not be allowed to pass under the protection of our ever sore and jealous neighbor, nor to become to all intents and purposes one of her outlying provinces. Lying almost in the direct road between Great Britain and India, our interests therein are too important to be neglected, even in times when weightier matters are pressing.

While on this point it may be pardonable to express the hope that negotiations will also be opened up with the Shah of Persia for the right to construct a line connecting Kurachee with Bassorah on the river Euphrates. English statesmanship should not overlook the fact that Russian money is rapidly pushing a system of railways through Persia to the head of the Persian Gulf. When these lines are completed, the dream of a British railway between the Mediterranean Sea and India will be plainly impossible.

This, however, is not the proper time or place to discuss these problems, nor is

it the place to try and unravel the equally interesting and still moot problem as to where the railway should start from. Alexandretta, Seleucia, Latakia, and a dozen other points on the Syrian coast have been named. Each possesses its separate commercial and political advantages, and each is subject to its particular disadvantages. Alexandretta has generally met with the preference; first, because of the natural shelter afforded to vessels through the magnificent Bay of Iskenderoon; and, next, because it lies in a direct line with the Bosphorus and Constantinople, to which city the framers of the scheme hope ultimately to continue the line. What we wish to consider mostly is the probable effect that its construction will exercise upon British shipping and how far it will affect the Suez Canal.

From a strategic aspect Suez would lose half or more of its present significance, and this could only result in a gain to commerce. With the railway in existence the Canal would no longer constitute our chief military road to India in time of trouble, troops being so much more readily and more expeditiously forwarded by rail; it would consequently cease in part to be a menace to the peace of Europe. The enmity of Europe would then center in Mesopotamia instead of the Delta as now; while the Canal to some extent at least would be surrendered to the cause of humanity, progress, and commerce. To neutralize it then would be no such impossible task, for the Euphrates railway would serve England's military needs in times both of war and peace, and those of other nations in times of peace alone. Having comparatively small interests in the East to serve, other nations might then consent to shut against their war ships the short cut to the Red Sea. That the railway would abstract any large share of the commerce now passing through the Canal is an argument finding no echo in the writer's mind. Some proportion of through traffic, especially light goods and those liable to spoil by long keeping would doubtless pass over the line; but it happens that economy is the chief *desideratum* which merchants have to consider, and the cost of double transhipment, together with the high freight charges entailed by a 900 miles railway journey, would more than eat up, I fear, any saving that might be effected by taking the shorter sea voyage up the Persian Gulf. Lesseps' Strait would convey just as much shipping between the Mediterranean and Red Seas, though the Company might lose some share of its prosperity in being compelled to lower its excessive tolls. This, however, would prove a general gain to the commercial world, not a loss, though the De Lesseps family might think differently.

Among other probable consequences there can be little doubt that Kurrachee would become the military port of India and in the course of years rival Bombay in magnificence; while regular steam communication would be established between those towns and Grain. Cyprus, of necessity, would be converted into our chief *place d'armes* in the Mediterranean, and upon it we should have to maintain a considerable army, supported by a fleet of powerful ironclads; while Alexandretta, or Latakia, or whatever other town the line started from, would leave its ineffaceable mark upon the history of commerce and might be expected in time to revive the glories of the Syrian cities of old.

Finally, there seems no cause to imagine that the construction of a line through the Euphrates Valley will exercise a detrimental effect upon our shipowning interests. It is more likely to impart a new stimulus to them. Fresh lines of steamers will have to be run between Grain and Kurrachee or Bombay; while a new and important port will be opened on the Mediterranean. Only good apparently can result to British commerce from the threatened competition with the Suez Canal Company; and, if that ill-disposed and selfish body experience some amount of harm, no one but its constituent members will have any occasion for moaning.

WATER MAINS IN LONDON.—There are now 828$\frac{3}{4}$ miles of water mains for the supply of London which are constantly charged. Of these the New River Company has 214 miles; Lambeth, 136$\frac{3}{4}$; Southwark and Vauxhall, 117; West Middlesex, 86$\frac{1}{2}$; Kent, 85; East London, 85; Chelsea, 67; and Grand Junction, 37$\frac{1}{2}$ miles.

THE TRAINING FOR STUDENTS IN CIVIL ENGINEERING.

By GEORGE L. VOSE.

From the Journal of the Association of Engineering Societies.

THE remark has recently been made that, while civil engineering is a *business* of great antiquity, it has only recently become a *science*. Without stopping just now to ask whether engineering has in reality become a science, we may very properly inquire whether anything that can correctly be called engineering science has made the business any better, or has enabled us to produce any better practical results; and, if so, in what that science consists. I ask these questions, as they seem to me to lie at the foundation of a correct understanding of what we should teach, and how we should teach it in the engineering school. To know how to teach, we should know first of all what we are required to teach, and what results we are expected to produce. These we learn best by a careful examination of the methods followed and the works constructed by our leading engineers.

We find at the outset that civil engineering in the United States is somewhat different from that in Europe, and in many respects very properly so. To have attempted in this country to carry out the methods followed in Great Britain and on the continent, would have soon put a stop to all internal improvements in America. The rapid and enormous development of the United States is due not simply to the railroad system, but to the *American* railroad system. Our early self-taught engineers at once saw that with our very limited means, and our vast extent of territory, a very much cheaper kind of engineering would have to be adopted for this country than was followed in the densely populated parts of Europe, where money was plenty and the territory was comparatively small. If we look at the works of Smeaton and Brindley, of Rennie and Telford, of Brunel and the Stephensons, we find a kind of engineering eminently English, eminently substantial, eminently expensive. The docks of Liverpool and London, the splendid roads of Wales, the stone bridges and viaducts through the kingdom, almost without number, the harbors and breakwaters, the works for drainage and reclamation of land from the sea, the older canals, and more recently the enormous network of railways, with their elaborate structures of iron, brick and stone, all bear witness to the energy and the skill of English engineers, but all at the same time illustrate a very costly kind of engineering. If we look at the engineers of the earlier works in Great Britain, we shall find a very large proportion of them to have been self-taught men, men who arose from the ranks—masons, blacksmiths, bricklayers, carpenters, men with but little of what we call education, and little or perhaps nothing of what we call science, but men of indomitable, courage, infinite patience, well-trained judgment and unbounded common sense, who by long years of persistent toil put themselves at the head of the world's engineers.

If we look now at the early engineering of the United States, we find that the requirement here was quite different from that in Europe. We were very fortunate in this country in possessing good natural seaports, and were thus saved the expense of the artificial harbors which have made so noted a feature in foreign engineering. There was found in North America a land traversed by magnificent natural water-courses, furnishing ready-made means of communication, which for a long time were quite sufficient for the purposes of our interior commerce. Civil engineering in the United States may be said to have commenced with the building of the Erie Canal, the construction of which first called out our native talent, and produced our pioneers in the profession, Benjamin Wright, James Geddes and Canvass White. The rapid spread of the canal system into Pennsylvania and Ohio produced many other admirable engineers; but the advent of a new mode of transport soon put a stop to canal work, and gave us the fathers of railroad engineering in the United States, Gridley

Bryant, Jonathan Knight; Benjamin H. Latrobe, Charles Ellet, John B. Jervis, John Childe, William Gibbs McNeil and George Whistler. Many of the most noted among these early engineers were, like their English brothers, entirely self-taught men, who had to feel their way along cautiously through the untried field of engineering work; and all of them owed their success mainly to their own indefatigable exertions, aided by strong native talent, and not to anything that could properly be termed engineering science or engineering education. There has been no more admirable feature in American engineering than the manner in which these early engineers adapted themselves to the requirements peculiar to our country, and molded their practice to the conditions imposed upon them. The long range of the Appalachian Mountains, lying as a barrier between the great central basin and the Atlantic coast, made an enormous draft upon the energy, skill and patience of the fathers of the American railroad system, and well was that draft honored by the engineers of the Baltimore and Ohio, the Pennsylvania and the Erie railroads. Not only have the methods employed by the engineers of those early roads given to this country the backbones of our system of interior communication, but they have served for examples the world over, as models for railroad location.

We may stop here a moment to note the fact that all through the early engineering of both England and the United States there was no such thing as any school for training the civil engineer. There was no such thing as a science of civil engineering. Engineering was in some sort a craft, but not a recognized profession. The works of internal improvement were comparatively limited in extent, and the demand for engineers was not larger than could be supplied by men of strong natural powers, with enthusiastic love for their work; men who had the genius to originate, and the ability and the perseverence to find out, what they did not know.

To come down a little later, we find the construction of public works rapidly increasing, and a corresponding increase in the demand for engineers. Many young men, drawn to an occupation which is always attractive to persons of a practical turn of mind, found employment as assistants to surveyors and engineers, and gradually the system of apprenticeship arose, under which a young man, wishing to become an engineer, entered an office for a fixed time, and paid a premium for learning what he could. Of course, as a general thing no attempt was made to teach him, but he was expected, or at any rate allowed, to keep his eyes open, and to see what was going on. About this time, too, a few books upon engineering matters began to show themselves, and the shelves of the offices furnished such food as Pambour on the Locomotive, Wood on Railroads, Vicat on Cements, Parnell on Common Roads, and the like. These works made very little attempt to be scientific, but were largely descriptive of actual works, and were thus valuable.

Foremost among institutions designed especially for the training of engineers, was the Polytechnic School at Paris. In this school it was recognized that civil engineering was largely a mathematical business, and it seemed to be assumed at the start that if a little mathematics was good, more mathematics was better, and the most mathematics was the best; and many leading minds in that eminently mathematical nation set to work to reduce engineering to a mathematical science, and volume after volume, upon the location of roads, the stability of retaining walls, the transportation of earth, the application of descriptive geometry to the construction of masonry, and other like matters appeared, in which all the resources of the higher mathematics were exhausted, and which showed the authors to possess every accomplishment except, perhaps, a little common sense. In establishing the earlier schools in this country, it was quite natural to look to the pioneer school in Paris, and in many places a system was imported not at all adapted to any practical engineering in this country, if indeed it was to that in any country. The fact that under such a system good engineers have been produced means nothing, as the same may be said of no system at all. We are not to judge a system of instruction by a few brilliant exceptions, but by the general average. While we may justly admire the great works of foreign engineers, and

while we have much to learn from their practice, at the foundation our system is better for us than any other; and we shall do better to let the plant which is native to our soil grow naturally, than to graft foreign branches on to it. The attempt to transplant the French system of engineering instruction into the United States has not been a success. American engineering is the best engineering for this country. Our students are to be American engineers, and we must fit them accordingly.

But it may be asked, is not this rather a narrow view to take? Is not geometry the same the world over? Is not the strength of a piece of iron the same in the United States as elsewhere? Are not the fundamental principles of engineering the same in all countries? Most undoubtedly they are. But, we may reply, the varying conditions under which we are to apply the fundamental principles of engineering may make it advisable to do very differently in one place from what we would in another. I stood a good many years ago with an English engineer upon the site of the present Niagara suspension railroad bridge, and I told him that it was proposed to carry railway trains across that river. He replied that it could not be done, because a tubular girder of 800 feet span, if strong enough, would fall by its own weight, and that a suspension bridge could not be made stiff enough to carry a railway train. The geometry and the iron of the English engineer were the same as those of Mr. Roebling, but Mr. Roebling had the genius for meeting a new problem, which the latter had not. The whole progress of engineering in this country has been a perpetual illustration of the successful solution of new problems. The very facts which to one man are an impassable barrier, become in the hands of another the very means of success. The grades and curves which by foreign engineers were pronounced impractible, if not impossible, in the hands of Mr. Latrobe were made to perform one of the greatest feats of modern engineering.

In deciding what course we shall follow the best to train the young engineer, we see at once that we have to do two things—to make him an engineer and to make him a man. The more symmetrically we develop our man the better the result will be, even in a special direction. Far too little attention has been given in our technical schools to anything like general education. Just as a variety of food is best for physical health, so is a variety of study best for mental health; and just as we need a foundation of the best general physical health in order to train a man for physical exertion in any particular direction, so do we need a basis of good general mental health in order to train a man for mental exertion in any special line. "A thorough technical education," says a recent writer, "embracing all that science and art can bestow, is not enough to produce the best industrial results. There is need of the additional discipline which comes only from the study of letters. The man must be *formed* as well as *informed* before he is fully educated even for practical purposes." Many years ago the Bavarian Council for Roads and Bridges decided on admitting into the body of government engineers none but those who before entering the Polytechnic School had followed a complete classical course. The administration of mines had also constantly required the same qualification. A better illustration of the thoroughly and symmetrically trained engineer can nowhere be found than the late Baron Weber, perhaps the best railroad expert the world has ever seen. He commenced with a thorough classical training; next he passed through the polytechnic school at Dresden; he then received a practical training, first as a pupil and afterward as constructor in the locomotive works of Borsig at Berlin, at the same time attending university lectures in political economy and the natural sciences. Finally he commenced his practical railroad course, beginning as locomotive engineer and working up through all the technical and administrative positions to the office of the General Manager; and later, having traveled through all civilized countries on a tour of inspection of public works, became Councillor to the German Empire.

We see at once that in laying out any course of study we are to keep in view a double object. We are to drill the student, and to give him useful information. Some studies furnish excellent discipline, but are of little or no practical use;

others are useful, but do not afford much discipline; while others again at the same time accomplish both of the above results. "Every branch of study," said the late Dr. Wayland, "should be so taught as to not only increase our knowledge, but also confer valuable discipline; and it should not only confer valuable discipline, but also increase our knowledge. If it does not accomplish both these results, there is either some defect in our mode of teaching, or the study is imperfectly adapted to the purposes of education." Studies more especially for discipline should, as far as possible, come early in the course, while studies more for use should come later, as having already the discipline, the student makes better progress. As one of our prominent engineers has put it, when a student has learned how to learn, he can quickly learn anything.

The study of mathematics has always taken a prominent place in engineering courses, and very properly so; but it is after all the more simple and elementary part of mathematics that is of the most use to the engineer. Recent discussions upon the subject of the training for civil engineers have called out some very decided opinions from authorities who are certainly competent to express themselves in this matter. "Much time," says Mr. Thomas C. Clark, "is wasted in our colleges and technical schools over the higher mathematics. Every engineer will agree with me that the cases where the use of the higher calculus is indispensable in our practice are so few that its study is not worth the time expended on it; and we have the highest authority for saying that unless its use is constantly kept up we become too rusty to use it at all." "It is true," says Mr. Fuertes," himself an accomplished professor of civil engineering, "that there are very few cases in which the engineer needs the higher analysis; that not one in a hundred uses it at all; that it cannot possibly be applied unless we are quite familiar with it; that, like correct fingering on a musical instrument, it makes severe demands on our time, and that it is easily forgotten, because much of its machinery is dependent on forms or processes that must be memorized for instant choice when needed." "Practical engineers," says Mr. Charles Bender, himself an accomplished mathematician, and a graduate from a German University, "generally do not place much confidence in long formulæ; and if they once have studied mathematics thoroughly, they lose the taste for these studies after some time of practice, since they have convinced themselves of the futility of ultra-refined theoretical speculations," "In our experience of nearly half a century as an engineer," says Mr. Julius W. Adams, "we have very rarely found that engineers possessing this peculiar facility for minute mathematical analysis, with the consequent reliance upon its infallibility which usually accompanies it, were safe guides, either in the design or execution of novel projects."

Many persons seem to think that if we can put anything into mathematical language we have done all that is necessary; that the mathematical mechanism can take the place of actual facts; that the lever is enough without the applied power. "We must not," says a recent writer, "confound mathematical skill in the making and manipulating of formulæ with science. There is a vast difference between the misuse of the higher mathematics and the proper use of those mathematical principles which lie at the foundations of all engineering operations." Mathematical skill must be tempered with a good deal of judgment before it can be of any very great use. It has been said by those who admit that the higher calculus is of little actual service to the engineer, that while it may not be really necessary for use, it is very desirable for discipline. This sounds quite well, but it is very doubtful if the average student gets from the study of the higher calculus the discipline that he is supposed to. It is very easy to deceive ourselves into believing that the student *does* get what by our theories he *ought* to get. Not many years ago the custom was very general in our colleges to oblige all students to go through the differential and integral calculus. This was done purely on the ground of discipline, for no one ever claimed that it was to be of any use to the student. It was found, however, after many years, that, except in rare cases, the student utterly failed to get any return at all commensurate to the amount of time given to this study. For the great num-

ber it was merely an inducement to shirk duty, and a means for getting slovenly habits of study. It is now almost universally abandoned as a required study in colleges. The fact is now recognized that much better discipline is had by doing a more simple thing well than by doing a difficult thing badly. To a certain extent a person must have mathematical genius to do good work with the higher calculus. An old mathematician being asked by what rule he performed a certain operation, replied, "By the rule of Gumption;" and it is certainly the fact that the inventive faculty, nay, even the imagination, enters as a larger and larger factor in the mathematics as we climb to higher and higher planes in that science. It has been said of the poet that he is born, not made. It may be said of the mathematician that he must be both born and made. Mathematical talent of a high order is rare, and any system of instruction that is based upon the assumption that all students can profitably spend a large amount of time upon an extended course of advanced mathematical work, I believe to be a faulty system. On the ground that we should do the greatest good to the greatest number, I hold that we should make our course in engineering study useful rather than difficult. It is much more important to make the student very familiar with the more simple things that he is going to use, than to cram him with the more difficult things that he will never use. Our instruction should be adapted to the average of good students, and not to a few exceptionally bright ones, always endeavoring, of course, to raise the average, and always providing advanced work for those who can take it. The school should be like a good garden for hardy plants, and not like a hot-house for forcing an unnatural growth. Mathematics is called an exact science, and those who have but little experience are apt to think that any mathematical operation must of necessity produce an exact result. This over-reliance on mathematical processes is a sure sign of inexperience. Only when the mathematical mechanism is applied to the right facts, and with correct judgment, do we get reliable results.

It is well understood among engineers that all ordinary engineering problems, mathematically considered, are quite simple. Look at any of our great engineering works, and see how much mathematics was needed to carry it out. Take from civil engineering all that the higher mathematics has ever done for it, and see how much it would be damaged. See what one of our great works we should lose, if the calculus had never been invented. A short time since there was held at Washington an examination for the position of civil engineer in the army. Government wanted four civil engineers. The number of applicants was very large, for the position was a good one, and a permanent one. The candidates were subjected to a long and searching competitive examination, conducted by five expert civil engineers. There was not a question from beginning to end that involved anything beyond the most elementary knowledge of mathematics or mechanics. The examination was marked throughout by fairness and common sense, the desired result being to get not an engineering scholar, but a man who would be of the most use to the government as a sound, practical engineer.

It is certainly not advisable to consume too much of the student's time in mathematical discussions of engineering questions, for not only are such discussions of little or no practical use, but the pupil acquires a habit of regarding all engineering problems as capable of solutions far more exact than is possible, considering the defects inherent both in materials and workmanship. A grave defect in our mode of instruction is that instead of fitting the student to deal with engineering problems *as they are*, we fit him to deal with these problems *as mathematicians assume them to be*. A glance at any of the ordinary text-books will show how much more they are mathematical than practical. The market has been flooded during the past ten or twelve years with more or less mathematical works upon bridge building, but we shall look a good while in these books for any information of practical use that we did not possess before. Had we more books like Clark's description of the Quincy bridge, or Chanute's work on the Kansas City bridge, we should be a good deal better off than we are; but,

strangely enough, we have to go to Europe for the best published illustrations of our own engineering works. The tendency of many recent writers to indulge in mathematical recreations has produced works far more interesting to the authors than valuable to engineers. We can hardly wonder, from the general aspect of many of the papers in our professional magazines, at the remark of one of our oldest and best engineers, that science seems to consist in burying the simplest facts completely out of sight under heaps of mathematical rubbish; or the criticism of another of our professional veterans, that such methods seem very much like using a sledge hammer to break an egg.

The idea that has sometimes been expressed that an engineer must at any time be able to go to the foundation of any formula which he may have to use, shows simply an entire lack of appreciation of the work an engineer has to do. Indeed many of the formulæ are found upon examination to have no foundation on which any reliance can be placed. A very large part of the rules in the books have been made, not by engineers, but by mathematicians, or by mere engineering scholars; and however admirable they may be as specimens of mathematical reasoning, they are of little or no use in practice. Take the whole matter of stone arches, of retaining walls, of dams, of the pressure of earth work, the results of the higher analysis are for the most part of no practical value whatever, and serve only to confuse and disgust the student with what treated in a simple and practical way may be made both useful and interesting. One of the most distinguished engineers has said with a good deal of truth that "trying to apply the higher mathematics to engineering is like looking into the clouds with a telescope of high power in search of facts within our grasp on the surface of the earth."

"If," says the late Milnor Roberts, "it was required to designate the one essential requisite of an engineer, we would place *judgment* first. An engineer to be great or strong must have other qualifications, but lacking that essential element, judgment, he would be incapable of availing himself even of brilliant talents." This point is of so great importance that I may be permitted to quote a few lines from a very masterly address delivered by the late Professor Faraday, before the Royal Society of London, on the Education of the Judgment. "A great deficiency," says Mr. Faraday, "In the exercise of the mental powers in any direction, is deficiency of judgment. Failure to draw correct conclusions comes far oftener from error of judgment than from error of sense. I believe that the judgment may be educated to a very large extent. There is one point in this education of the judgment which is very important, and very difficult to deal with, because it involves an internal conflict. It consists in the tendency to deceive ourselves regarding all we wish for, and the necessity for resistance to all these desires. It is impossible for any one who has not been constrained by the course of his occupation and thoughts to a habit of continual self-correction to be aware of the amount of error in relation to judgment arising from this tendency. The force of the temptation which urges us to seek for such evidences and appearances as are in favor of our desires, and to disregard those which oppose them, is wonderfully great. The inclination we exhibit in respect of any report or opinion that harmonizes with our preconceived notions can only be compared in degree with the incredulity we entertain toward everything that opposes them. I believe that point of self-education which consists in teaching the mind to resist its desires and inclinations, until they are proved to be right is the most important of all. One exercise of the mind which largely influences the power and character of the judgment is the habit of forming clear and precise ideas, so that vivid and distinct impressions of the matter in hand may remain. In like manner, we should accustom ourselves to clear and definite language, giving to a word its true and full but measured meaning, that we may be able to convey our ideas clearly to the minds of others. When the data have been collected, and we have succeeded in forming a clear idea of each, the mind should be instructed to balance them one against the other, and should not be allowed carelessly to hasten to a conclusion. Again, we should drill ourselves to being

able to form a *proportionate* judgment. The mind naturally desires to settle on one thing or another, and that with a degree of absolutism which is irrational and improper. In drawing a conclusion it is very difficult, but not the less necessary, to make it *proportionate to the evidence;* and in some cases the exercise of the judgment ought to end in absolute reservation." In commending these words of Mr. Faraday to the student, we may add the not less important advice of a distinguished English geologist, Sir Henry La Bêche: "It can only be amid a thousand errors, and by a determination to abandon our preconceived opinions when shown to be untenable, not by pertinaciously adhering to them because we have once adopted them, that we can approximate toward the truth. By strictly advocating a particular theory, prominently displaying the facts only which appear to afford it support, we are in perpetual danger of deceiving ourselves and others. Facts of all kinds, whether in favor of or against our views, should be honestly brought forward, in order that those whose opinions are unprejudiced may fairly weigh the evidence adduced." The world has just lost a man who was remarkable for absolute perfection of judgment; and we as engineers may well learn from the greatest of modern philosophers, who during twenty years of intense labor persistently withheld his judgment, but patiently accumulated the facts upon which the doctrine of evolution now firmly stands.

In all our training of the engineering student, it is to be kept in mind that we are not only to give him the best standard information for his future use, but we are also to give him, as far as possible, the power of acquiring information, and of knowing how to use it when he gets it. Above all we must not narrow nor distort his mind by partial training, so that after his studies are completed he will have to spend half a dozen years in unwarping it. We must rather give his mind that healthy elasticity that shall enable it to maintain its true form under all conditions. We are not to furnish the student with blue glasses nor with green glasses, but with white glasses, through which he shall see things as they are. We should also use every means to make the pupil as he progresses rely more and more upon himself. It will, perhaps, be asked if we expect to give the student anything that will take the place of natural talent. We never can find anything to take the place of hard work; we never can find anything to take the place of devotion to duty; we never can find anything to take the place of honesty; but we can find something, which, as far as it goes, will take the place of natural talent, *i. e.*, artificial talent or education. The number of engineers possessing any very decided engineering genius is and always will be small. The great mass of the profession will always be, as it always has been, composed of men of average ability, who rely largely upon a thorough training for their business. The engineering works in this or in any other country which show brilliant genius are quite few. The greater part are not works of genius, but of good, practical, business capacity.

Suppose I should take a young man to give him private instruction in civil engineering. How would I go to work? Would I put Weisbach or Rankine into his hands, and tell him to read those books? Not at all. I would take him out with the transit and level. I would show him how the simplest things were done, and I would make him do them himself over and over again until he knew the practical detail thoroughly. Then I would show him the mathematical principles underlying that much practice; and little by little I would make him rely on himself for his methods of proceeding. Next I would show him some of the materials he is to use. I would take him to the quarry, to the brick-kiln, to the rolling mill and the foundry, and have him see the process of obtaining the materials of construction. I would show him where and how these materials are employed in engineering works. He should thus find what tension, compression, cross strain and shearing mean. He should see these materials broken under various conditions. He should learn by inspection what the fracture of various kinds of iron indicates. He should learn to judge of the quality of materials by actual contact with these things. Next, I would show him how these various materials are combined in engineering structures, with the appa-

ratus used in such work. I would have him note carefully all of the practical details of building, the mixing of mortars and cements, the laying of brick and stone. I would keep him ever on the watch for bad workmanship and faulty methods. I would be especially careful to call his attention to any defective structures, to any signs of failure, and make him find the reasons for such defects. I would have him at every point note carefully the difference between the methods of the workman and the methods of the books. He should find, what the workman rarely, if ever does, the *reasons* for his methods. At the time he is thus laying the foundation of the facts of engineering, I would step by step show to him the mechanical principles underlying those facts. I would not bother him with fine-spun theories in regard to the strength of materials, the theory of elasticity, or the stability of structures; but I would show him simple modes for doing simple things. I would never for a moment let him suppose that there was such a thing as a conflict between practice and theory. I would so train him that he should never regard science and art as two separate things, but rather as two parts of one and the same thing. After he had got steady on his legs, I would gradually bring him to see more complex and difficult problems. I would show him plainly that many problems are quite indeterminate, and that often a purely empirical method of solving a problem is not only sufficient, but is better than any other. Above all, I would train him in such a way that he should learn to know, as Lord Bacon has put it, "the relative value of knowledges." Finally, I would take every possible means to make him well poised and absolutely honest in judgment.

We cannot, of course, deal with large classes as we would with an individual, but we can certainly approach the method. At all events we need not go out of the way to invert the mode. Our courses of study assume all students to be alike. This is to a certain extent necessary; but as the pupil advances the work may be made more and more individual, to some extent: we may thus fall in with nature and work with her, instead of pushing against her. We must not only be sure that the right subject is presented in the proper manner and at the right time, but we must remember that to have the matter properly presented is only half the work. It must also be properly received. The great mass of students are always able to understand any ordinary subject when it is properly presented, and we must make sure as we go along that the pupil actually gets what we intend he should. No two students are alike; each has his own difficulties, each looks at a subject in his own way; and not only is it quite proper that he should, but the general progress of a class is far more satisfactory from this difference in its members than it would be were they all alike. The result of our course should be not so much to have made the student read certain books, as to make him able to do certain work. A man may have Weisbach and Rankine by heart, and yet know little or nothing of engineering; he may apparently have a perfect knowledge of all the books, and yet have no real knowledge of the subject.

We can in teaching make a subject repulsive or we can make it attractive. There is a vast difference between simply hearing lessons and giving instruction. The duty of an instructor is not merely to unload all the knowledge he has at the student's door, never waiting to see that he takes it in and uses it. We are not to regard the engineering student as a school boy, but we are to take him by the hand and make a companion of him. There should be always attraction between the teacher and the pupil, never repulsion. The study of civil engineering cannot be made easy, but it can be cleared of unnecessary obstructions, and I regard it as a prominent part of our duty to do this. We have got to work and to make the student work; but we must work along the line of least resistance. We want our labor to produce useful result, and not to be wasted in overcoming friction.

We often hear it stated that the business of the school is not to deal with details, but with what are somewhat vaguely termed general principles. I believe there never was a greater fallacy. No general principle can possibly be applied to engineering construction except by means of practical details; and in many cases the details are more important than the principles. I believe

that just as engineering practice preceded engineering science, so in our course of instruction we must have a soil of practical conceptions in which the theoretical plant can grow. To give a young man an exhaustive theoretical discussion in the school, and to tell him that by and by he will run across the practical details, is very much like setting out a plant upon a brick sidewalk, and trusting to luck to get some earth about its roots at some future time. We can stop in the school to study and discuss details with the student, but it is not the business of an employer in actual work to instruct his assistants, and he never does it. I don't mean to say that experience can be taught in a four years' course, but there are a great many results of experience that can be presented to the student which will save him a vast deal of time and trouble, and at the same time show him exactly what his work is like. There is nothing more important than that the student should be made to see very plainly that no mechanical philosopy whatever can be applied to practice which is not subject to the unavoidable imperfections of materials and of workmanship, and I hold that one of the most important things we have to do in the school is to show how far the contingencies of workmanship limit the applications of science. We should make the connection plain between the science of engineering and its practical applications. We should give the student that knowledge of practical details which shall enable him to modify his theoretical knowledge in accordance with the requirements of practice. For lack of this the student wastes his time, the practitioner blunders along without the aid he might have, and a fancied conflict appears between two things, neither of which can do its best without the aid of the other.

It has sometimes been said that the work of the school is not so much to enable a young man to be at once serviceable to his employer, or profitable to himself, as to lay the foundation on which he can build the highest professional character hereafter. This remark would seem to indicate that these two results are in some way discordant. If engineering is properly taught, there can be no possible conflict here. There is no reason why the same process should not produce both of these results. There is no possible reason why the instruction should not be given with a view to immediate usefulness and at the same be given in such a manner that it can be expanded to any desirable extent.

There is one point upon which I am very particular not to be misunderstood. I do not wish to be thought in favor of omitting the study of any part of the higher mathematics. I am not one of those who think that nothing should be taught unless we can see in it some immediate use. I make no objection to the time given in our engineering schools to Descriptive Geometry. It is of no practical use. Very few engineers know anything about it, and those who do never use it; but I regard it as one of the best studies we have for discipline, as it develops a faculty in the student which is reached in no other way. The modern languages again are not essential for the engineer. I know the theory is that he reads the French and German engineering works. I know equally well the fact that he does not. For all that I regard the study of the modern languages, or of any language, as of great importance to all students, and I should value it as a most useful part of the education of an engineer, though I knew that he would never use it in his life.

It is very necessary that the student should be taught to be careful about little things, and not to think because he may be all right in the matter of general principles that the details will look out for themselves. It would, indeed, be more correct, in many cases, to say: Look out for the details and the general principles will take care of themselves. On the other hand, the student should learn, what is not less important, when *not to be exact*. He should learn that a lack of method is sometimes preferable to too much method; that very often a purely empirical mode is better than any other. It is in many cases neither bad engineering nor bad logic to assume a solution for a problem and verify it afterwards. We might, perhaps, make a general rule for finding the position of a slope stake in a side-hill cutting, but we can put the stake in by the common mode of trial a good deal quicker than we could apply a general formula.

In laying out our work in the engineering school, it is very important to make the course comprehensive. We owe this not only to the students, but also to the school; for by so doing, we need not only deal more fairly with the young men, but we insure a more steady supply of students, as we make the school more independent of fluctuations of special departments of engineering business. Many of our schools seem to have assumed that the subjects of railroads and bridges cover the whole field of engineering, and ignore entirely the matters of hydraulics, water supply for cities, sanitary work, drainage and irrigation, river and harbor work, and other equally important branches. Especially do the schools appear to have neglected altogether any endeavor to make of the student a good business man. There can certainly be no more important exercise for the engineering pupil than the careful study in detail of well-made specifications, of contracts, and of the strictly business portion of engineering operations, and certainly nothing has been more completely neglected. We graduate young men who are more or less familiar with the mathematics, chemistry, physics, geology, astronomy, but quite unable to examine the simplest accounts of a contractor, or to judge in any way of the economy with which any work is being carried on. The power to handle large bodies of workmen, and to obtain the greatest useful result from a given expenditure of money, is no doubt very largely a natural gift; but a very useful amount of this power can certainly be gained by close study and careful attention to detail, and this point should at all times be kept before the student.

It was easier in old times to be a noted engineer, when the number engaged in the business was small, than at present, when the profession is large. We have now to supply a great body of engineers. The work of the school is to give a good education to the average student. The masters in the profession will still be few and far between, and either with or without the aid of the school will take the prominent places. We must expect now and then to see a genius arise superior to all schools, who sets all educational theories at defiance and strides out far in advance of the best graduates. Teach as we may, Nature will continue to do as she always has, graduate her favorite pupils in her own manner.

In deciding just what to teach in the engineering school we must remember that we cannot teach everything in four years. We should devote that time to the more elementary things and to the more important things, while the more advanced but less essential things should be made the subjects for a post-graduate course. In the latter might come the higher mechanics, the higher surveying, geodesy, practical astronomy, experimental physics, and the like, for such students as have a taste for these things. In this part of the course too, the individual tastes of the student may be allowed a certain degree of control in the selection of studies, which is not practicable, even if desirable, in the more elementary part of the course. I regard this as a solution of many difficulties which have developed under our present system of instruction, which seems to me defective in attempting to crowd too much and too difficult work into a four years' course for a class of students quite young and quite unused to higher technical studies.

In carrying out our course of training for the young engineer, we are never to lose sight of the fact that we are not only to teach our students to be engineers, but also to be men. The civil engineer has a connection with the public welfare that no other professional man has. Quackery is more fatal in this than in any other business. The hundreds of millions of passengers that annually travel over our railroads place their lives in the hands of the engineer. He is bound to provide for their safety. It is his privilege and his duty to do so. In the words of England's greatest engineer, "A man's ability is a debt he owes to the welfare of his fellow men." In all his labor the engineer should make self subordinate to the general good. It is not the business of an engineer to erect monuments to himself with his employer's money. That money is given to him in trust, and to waste it to gratify his own pride is violating that trust. To do the required work in a proper manner for the least money is what is re-

quired of the engineer. The student cannot too carefully study the lives of the older engineers, Smeaton and Brindley, and Rennie and Telford, and the Stephensons in England; Gauthey, Navier, Perronet, and Rondelet, in France, and Bryant and Baldwin, Jervis and Childe, Knight and Latrobe, Geddes and Wright, McNeil and Whistler, and a host of others in this country. Let him carefully study the lives, the character and the works of these men, and above all, let him take to heart these words of one of the foremost living members of the profession, a man of whom American engineers are justly proud: "What should be our highest aim as engineers? Should it be to stand at the head of the profession, or to scrupulously discharge the duties of the positions in which we are placed? If the former, then we have many chances of failure to one of success, which will so often depend upon circumstances entirely beyond our control. If the latter, then success depends upon ourselves, for it is assured by a simple and constant attention to the requirements of each occasion as it arises." Engineering is no less a business than a science, and the most successful engineer will be as much a business man as a scientific man. Our roads and railroads, our locks and canals, our bridges and tunnels, our sanitary and hydraulic works throughout the country have been the result of very simple science, but of a great deal of practical skill and of good sound business talent.

As a science, engineering is a very simple one; as a business it is often exceedingly complex. To train our young engineers so that they may produce the greatest useful result with the least expenditure of money, it must be kept in mind that to a thorough knowledge of the more elementary science must be added the most careful and faithful attention to the practical details of engineering business.

THE INDUCTIVE AND CONDUCTIVE CIRCUITS.

By JOHN T. SPRAGUE.

From "The Electrician."

It is generally considered that static electricity and dynamic electricity require distinct treatment. The result is that few people acquire clear conceptions as to both branches, and the formulæ and laws of the one are apt to prove an incumbrance when studying the other. The real distinction between the two is, however, nearly unknown, and not pointed out in any of the books. That distinction is that there is no such thing as a *quantity of static electricity*. It is quite true that we have two definitions of such a quantity, but those definitions themselves disprove its existence when studied.

The coulomb appears to be a unit of quantity, and it really is so as to dynamic electricity. The microfarad appears to be a receiver capable of comfortably holding a quantity of electricity like a pint bottle would a quantity of air, and that in ratio of the pressures put upon it.

The coulomb is, however, a quantity of electric *action*, not necessarily a *quantity of electricity*, even of dynamic electricity, because its truth and utility are equal, whether we consider electricity as an entity, a fluid, or as merely a function of molecular or ethereal motions and changes. Its value is fully definable as a material, actual quantity, because it releases a definite weight of hydrogen or other substance. This gives it a quantitative material value. A micro coulomb is one-millionth, and we can bottle this up in a microfarad and take it out again. Is that quite sure? Is it *electricity* we have put into our bottle?

What is the microfarad? The only essential part of it is a *dielectric*. The coatings only serve as the neck of the bottle, a pathway—electrodes. What, then, is a dielectric? It is a substance in which a certain state of *stress* can be produced, developing a *field of force;* that field of force is of such a nature that it is produced by what we call electricity, and will give us back the energy stored up in the stress as electricity again. Then it may be energy stored under par-

ticular conditions, not electricity, just as in secondary batteries we can store energy in the form of chemical affinity ready to reproduce electricity.

The other unit of electro-static quantity is that quantity which, placed at unit distance, repels an equal similar quantity with unit force. But the very definition tells us that this is a quantity of a force; it is simply the reaction of the "field of force" existing between the two electrodes.

Returning to our bottle of air, we find in it two things, a "quantity," the air itself—a "pressure" exerted by the air. Are not these the two things we find in electricity—a something definable as a "quantity" in dynamic electricity, which something exerts a "static pressure," related to the energy charged upon the "field of force" generated in that air? In this case, however, the air itself plays the double part; in electricity, whether there be a quantity of it having existence or not, it needs another substance, the dielectric, to store the energy, which, however, it may be said, corresponds to the material of the containing bottle.

The distinction drawn does not depend on the analogy, for this always fails at some point. The point itself is that the phenomena of static electricity are related, not to quantities of electricity, but to energy operating in a field of force; whenever "quantity" comes into play, as in discharge, we are no longer dealing with static, but with dynamic electricity. To make this clear it is necessary to consider some of the actions which occur.

According to the mathematical theory of electricity, current, &c., discharge, &c., are due simply to *difference of potential*, the actual position of the two points on what we may call the "scale of potential" having no influence. This is, of course, analogous to currents generated in a column of water, which may be regarded as a "scale of potential;" such a current issues from any point in the column as is due to the head of water above that point, however high up in the scale it may be itself.

The same effect will arise between two points in an electric circuit, whether those points are at + 15 and + 5 potential as regards zero, and though both of them have free + charges, as would occur between two points at + 5 and — 5, with equal free + and — charges. The facts are, of course, true, and for some of the purposes of calculation, the theory has its advantages. But the theory is not true as a fact of nature. The water analogy itself disproves it; the column of water below the point at which current passes is inert, *it is not in the circuit.* The same is the case with the electric circuit. It is true that we can have two Leyden jars charged to such differences, with their external coatings connected together, as will represent the scale of potential, the external coatings being the + and —. But then we may connect the junction of the external coatings to the theoretical zero of potential, the earth, and no current will pass. The analogy to the opening in the column of water fails. But why? Simply because we have two distinct inductive circuits. Each jar is complete in itself, just as a battery cell is. We can discharge the jars singly, just as we can take current singly from two cells joined in series, or we can discharge them in series with the effect due to the sum of the potentials, just as we can use the cells.

In fact, each jar, *i. e.*, each inductive circuit, has its own scale of potential, of which the — is at zero. The theoretical, or earth zero, is a mere artificial invention for purposes of calculation; it is precisely the same with the column of water. The total height of the column has no actual relation to the result, and the zero is not the earth's level (in fact, if anywhere, it would be at the earth's center); but for each current the real zero is the point at which it issues.

To meet the fact that no discharge will occur at the common junction to "earth," although that junction is at + potential, the other artificial doctrine of *bound* electricity is invented. The free charge on the inner coatings dissimulates an equal quantity on the corresponding outer coating; but what is the use of this complication when the case is absolutely analogous to that of the two galvanic cells? As long as the cells are open, they are under identical conditions with the charged jars; in both there is a break of connection—an inductive circuit between the poles, which the force cannot break down. Under these circumstances

we can insulate the jars, either connected or separate, and we can give them a *free charge*. But what is this but adding a third inductive circuit? We can even charge the external coatings + or —, but in so doing we simply make the outside surfaces the one coating to the air of the room to which the other coating is the surrounding surface. We can even put opposite free charges on the two jars in the same manner, and we can make these charges either the same or the opposite of the charges which their inner surfaces bear as regards the inner coatings.

All this becomes perfectly clear when we examine each separate inductive circuit as we should the circuits of currents, which every one knows may be absolutely distinct though they all unite at a common point, or even traverse some part of a common conductor.

We may now contrast and compare the two orders of electric circuits.

The *conductive circuit* consists of matter which allows electrical action to take place in the form of current, or we may say it permits electricity to pass. It does so in quantities related to the electromotive force, to the conducting capacity of the material substance, and in producing current the electricity expends energy.

The *inductive circuit* consists of matter which does not transmit electricity, but admits of the formation of a field of force manifested as *charge* at its opposite sides. Such "charge" is proportional to the potential, to the inductive capacity of the material called the dielectric, and in producing charge the electricity expends energy.

It will be better now to present the relations in parallel columns:

Static.	*Electricity.*	*Dynamic.*
Energy *potential;* stored in a field of force, as stress in a dielectric	means	energy *kinetic;* acting in a conducting path along molecular chains.
Inductive.	*Capacity.*	*Conductive.*
Area of dielectric. Spec. ind. capacity of dielectric.	varies as	area of conductor. Specific conductivity of material.
Thickness.	inversely as	length.

Inductive.	*Resistance.*	*Conductive.*
Reciprocal of conductive capacity.	is the	reciprocal of conducting capacity.
Charge.		*Current.*
Potential in Volts.	is as	electromotive force in volts.
Resistance.	inversely as	resistance.
Inversely as the several resistances.	divides among several circuits.	inversely as the several resistances.
Lines of forces under stress.	is related to and dependent on	lines of equivalent molecules forming chains.
	Energy, or Work.	
Square of charge in unit or equal resistance.	is as	square of current in unit or equal resistance.

FORMULÆ.

Charge $\frac{E}{R}=Q$ Current $\frac{E}{R}=C$

Potential $Q \times R=E$ Electromotive force $C \times R=E$

Resistance $\frac{E}{C}=R$ Resistance $\frac{E}{C}=R$

As to the capacity, the specific inductive capacity is measured in its own terms, by the charge received under unit potential by a unit dimension, as, for instance, a square foot of 1 mil. in thickness of the material. Specific conducting power is usually and most conveniently measured as a resistance of a unit dimension, such as a wire 1 foot long and 1 circular mil. in area. Resistance and capacity being reciprocals of each other, it is indifferent under which term it is measured.

The influence of thickness of dielectric is taken here under its simplest form, as a plate whose area vastly exceeds its thickness, which is practically in the form of concentric spheres of very large radius. This is correct, not only because it is simple, but because the comparison is really to be made between the areas which would transmit a unit of current or take up the same unit as charge, and this latter area is many million fold in the dielectric what it is in the conductor.

RETAINING WALLS.

By E. SHERMAN GOULD.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE title of this paper may draw a smile—or perhaps a sigh—from the readers of VAN NOSTRAND'S MAGAZINE, as their eye falls upon the familiar words. And indeed it might well seem that but little is left to be said upon what has become one of the threadbare topics of engineering literature. Still, in spite of all that has been written upon the subject, if we were asked to mention an author to whom one could go for full and intelligible information respecting the calculation and general rationale of retaining walls, what name should we give?

Without further expanding our preamble, we will at once state that a very excellent work has recently appeared from the press of I. Baudry, in which the matter is treated with such marked ability, that we feel it almost a duty to consign some of its most useful teachings to the pages of this Magazine, as the best means of making them known to American engineers.

This work is entitled "*Etudes théoriques et pratiques sur les murs de soutènement et les ponts et viaducs en maçonnerie*, par J. Dubosque."

The author establishes, and we here repeat for convenience of reference, the following well-known fundamental formulæ:

$$Q=\frac{1}{2}\delta h^2 tg^2\frac{a}{2}$$

$$M_Q=\frac{1}{6}\delta h^3 tg^2\frac{a}{2}$$

$$M_K=\frac{\pi h x^2}{2}$$

in which Q represents the thrust of the earth; δ the unit weight of the earth; h the height of the wall and sustained bank; a the angle which the natural slope makes with the vertical, and M_Q the overturning moment of Q. M_K represents the resisting moment of a vertical wall, of which x is the uniform thickness and π the unit weight of the material of which it is composed. He then puts

$$M_K=2M_Q,$$

using a safety factor of 2. From this last relation, he draws

$$x=hgt\frac{a}{2}\sqrt{\frac{2\delta}{3\pi}}.$$

He simplifies this formula by giving to the Greek letters their approved approximate values. He gives, first, to δ the value of 106 lbs. per cu. ft., and to π, the value of 137 lbs. per cu. ft.; this gives $\frac{\delta}{\pi}=0.773$. Assuming, first, $a=45°$ (slope of 1 to 1) he finds, $x=0.3h$.

Next, assuming $a=56°18'30''$ (slope of 1.5 to 1) and taking the corresponding practical value of $\delta=112$ lbs. per cu. ft. which gives $\frac{\delta}{\pi}=0.82$ (nearly) he finds

$$x=0.4h,$$

averaging $$x=0.35h.$$

This, Mr. Dubosque gives as the proper thickness, expressed in terms of height, for ordinary vertical walls without surcharge. We may venture a little further in the path of simplification, and write his general formula for such walls

$$x=\frac{h}{3}.$$

Further on, he solves the three fundamental formulæ given above, in terms of h. Thus, using values for a and δ corresponding to a slope of 1.5 to 1, he finds

$$Q=16h^3,$$

$$M_Q=5.4h^3,$$

and, using the maximum value of $x=0.4h$,

$$M_K=176h^3\ \ 11h^3.$$

Dividing one by the other,

$$\frac{11}{5.4}=2+,$$

he recovers his proposed factor, 2, of safety.

This vertical wall, with uniform thickness equal to $\frac{4}{10}$th of its height, and sus-

taining a bank of earth of equal height, having a natural slope of 1.5 horizontal to 1 vertical, the weight of the earth being 82 per cent. of that of the masonry, and including a factor of safety of 2, he calls the "typical wall." Any other wall, of whatever shape, having a resisting moment equivalent to that of this type, will fulfil the requirements of safety, barring, of course, exceptional densities and slopes.

This forms the key to Mr. Dubosque's method. Any required dimension of a wall of given section is obtained, by putting the moment of such wall of the above (or any given) thickness, in such form that the required dimension shall be the only unknown quantity.

Thus, let it be required to design a wall having an exterior batter, of given height, and given top thickness. The unknown and required value is then that of the bottom thickness. Assume a vertical wall, of equal height, with an uniform thickness equal to E, offering the necessary resisting moment. Let B represent the required bottom thickness of proposed wall, and b its given top thickness. The readiest way to obtain the resisting moment of proposed wall is probably to calculate it as if vertical, with uniform thickness equal to B, and then deduct moment of triangle having a height equal to h, and a base equal to $B-b$. The moment of the equivalent, given, vertical wall of thickness E being $\frac{E^2h}{2}$, we have $\frac{B^2h}{2}-\frac{(B-b)'}{6}\times h=\frac{E^2h}{2}$,

whence

$$B=-\frac{b}{2}+\frac{\sqrt{3}}{2}\sqrt{b^2+2E^2},$$

or $$B=-\frac{b}{2}+0.866\sqrt{b^2+2E^2}.$$

A numerical example is given, in which it is required to transform a vertical wall 5 meters high, with uniform thickness of $1^m.35$, into one of equal height and equal stability having a top thickness of $0^m.60$, vertical back, and battering face. These data give $B=1^m.43$. It will be observed that this transformation of section, while leaving the stability unimpaired, occasions an economy of 25 per cent. in material.

The same principle is used in investigating the subject of counterparts, or buttresses. It is known that a considerable economy of material may be effected by building a light wall reinforced by buttresses, which may be placed either against the face or back of the wall. The former is the more advantageous position for them, as they there oppose most efficaciously the overturning moment of the earth pressure; placed against the back, they have the advantage of not encroaching upon available space, and of cutting up the earth prism resting against the wall. One of the principle objections to placing them at the back of the wall is, that the earth pressure tends to tear the rest of the wall away from them, whereas in the case of an exterior position, the wall is pressed against, instead of from them.

The required data in regard to counterforts are, their distance apart, their thickness, the thickness of the intervening wall or "mask" (as Mr. Dubosque terms it) and the amount of their projection beyond the mask. Of these, all but the last are determined from the successful practice of the best constructors. Mr. Dubosque gives: distance between two adjacent counterforts, in the clear, 3 meters (say 10 feet); thickness of each counterfort, 1 meter (say 3′ 4″); thickness of mask, from $\frac{1}{7}$ to $\frac{1}{8}$ of the height. We have now only to determine x, the projection of the counterfort.

Referring to the figure we will consider the section of wall contained between the planes AB and CD, situated 4 meters apart. And first, to calculate the moment of the portion of mask *abcd*. The height of the wall will be always represented by h, and the thickness of the mask by $\frac{h}{c}$. The weight of the mask *abcd* is

$$P(abcd)=\frac{4h}{c}\times\pi h.$$

Its lever arm is $\frac{h}{2c}+x$. Its moment is therefore

$$M_K(abcd)=\frac{4h}{c}\times\pi h\times\left(\frac{h}{2c}+x\right)$$
$$=\frac{4h^2}{c}\times\pi\left(\frac{h}{2c}+x\right).$$

The weight of the counterfort *efgh* is

$$P(efgh)=\pi hx.$$

Its lever arm is $\frac{x}{2}$, and its moment

$$M_K(efgh) = \pi h x \times \frac{x}{2} = \pi h \frac{x^2}{2}.$$

The sum of these two moments is, for a section 4 meters in length,

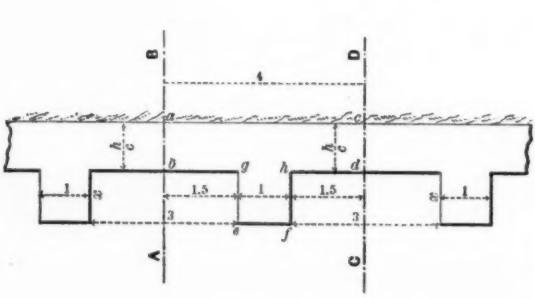
$$\frac{4h^3}{c} \times \pi\left(\frac{h}{2c} + x\right) + \pi h \frac{x^2}{2}$$

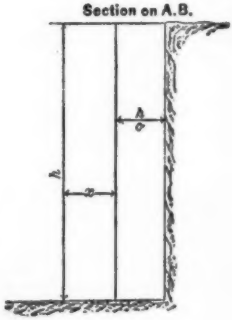
which, reduced to the unit of one meter, becomes

$$\frac{h^2}{c} \times \pi\left(\frac{h}{2c} + x\right) + \pi h \frac{x^2}{8}.$$

Making this equal to the resisting moment of the typical wall, we obtain

$$\frac{h^3}{c} \times \pi\left(\frac{h}{2c} + x\right) + \pi h \frac{x^2}{8} = \pi \frac{0.4^3}{2} h^3.$$





This equality takes the shape of the following equation of the 2d degree:

$$x^2 + \frac{8h}{c}x + \left(\frac{4h^3}{c^3} - 0.4^3 \times 4h^2\right) = 0,$$

whence

$$x = -\frac{4h}{c} \pm \sqrt{\left(\frac{4h}{c}\right)^2 - \left(\frac{4h^2}{c^3} - 0.4^3 \times 4h^2\right)},$$

which becomes, after reduction and simplification,

$$x = \frac{h}{c}\left(-4 \pm \sqrt{12 + 0.64c^3}\right).$$

This equation shows that as c increases the thickness of the mask diminishes, the value of x increases, and the total cube of masonry diminishes. There is therefore an economic advantage in increasing c as far as possible. As we have just seen, experience gives a value to this factor of from 5 to 6. That is, the thickness of the mask may be diminished to $\frac{1}{5}$ or $\frac{1}{6}$ of the height of the wall. Using 5 as the value of c, and considering only the positive sign of the radical, we obtain the simplified value of x,

$$x = \frac{h}{4}.$$

If we adopt a slope of 1 to 1 and take the corresponding value of δ, we obtain, calculating as before, but using the minimum value of $0.3h$ for the thickness of the equivalent vertical wall, we get, in round numbers,

$$x = \frac{h}{8}.$$

Calculations for interior counterforts are made in a similar manner. The same figures will answer for this case if we consider the earth placed on the opposite side. The value of the symbol remaining the same, we have, in the case of a slope of 1.5 to 1, and a typical wall of thickness $0.4h$, a value for x,

$$x = \frac{h}{c}\left(-1 \pm \sqrt{0.64c^3 - 3}\right),$$

whence, in round numbers, $x = \frac{h}{2}$.

For a natural slope of earth of 1 to 1, using the same data as for the similar case with exterior counterforts, we get, in round numbers,

$$x = \frac{h}{3}.$$

As regards sliding, the familiar assurance is repeated that a wall secure against overthrow is thereby secure against slid-

ing. Thus the force provocative of sliding is $Q=16h^2$; the resistance to same is the weight of the wall multiplied by the coefficient 0.76 of friction. The resistance to sliding of the typical wall is therefore $41.6h^2$. The factor of safety is therefore given by the relation

$$\frac{41.6}{16}=2.60.$$

There is besides, the cohesion of the mortar, intentionally neglected.

It may be well to mention that in this paper we have given the numerical values of Q, M_Q and M_K, in pounds, per running foot of wall or bank, whereas in the original they are naturally in kilogrammes per running meter. For purposes of comparison it might be convenient to reduce their numerical coefficients to a simpler, imaginary unit, which we can do by dividing them all by 5.4. This would give very nearly the following relations:

Thrust or horizontal component of earth pressure,

$$Q=3h^2.$$

Overturning moment of same,

$$M_Q=1h^3.$$

Resisting moment of typical wall,

$$M_K=2h^3.$$

The above is a rapid sketch of a few noteworthy features of the admirable work of Mr. Dubosque, in so far as it relates to a certain class of retaining walls. The sections devoted to the different varieties of surcharging to which a wall may be subjected, the practical observations upon the construction of retaining walls, and the entire second part of the volume which relates to arches, piers and abutments, are left, necessarily, unnoticed.

THE PANAMA CANAL.

From the "Nautical Magazine."

In the midst of the grave crisis which has arisen in connection with Egyptian affairs, the Panama Canal question seems to have quite lost its hold on the public attention. That such should be the case is perfectly natural. At the present time the difficulties in which we find ourselves involved in the East are not to be compared with the more problematical dangers that are looming in the West. In the one case they are only too definite and real; in the other they exist merely on paper; and, while one question is being decided by the sword, the other still forms a subject for the diplomatist's pen. Yet, in spite of the small importance which the Panama Canal affair seems now to possess, in comparison with the Egyptian difficulty, it is by no means unlikely that the day will arrive—and that at no distant date—when the case will be otherwise, and when the former will become a question of the utmost gravity.

As regards the possibility of constructing the Canal there seems now to be no room for reasonable doubt. It appears to be simply a question of money, and, looking to the facility with which the means for carrying out large undertakings of this class are raised at the present day, it becomes tolerably clear that the project is by no means such a chimera as some of its objectors have supposed. The indomitable M. de Lesseps is fully convinced of the practicability of the scheme, and he has thus far experienced no difficulty in imparting a share of his own confidence to those who can provide the sinews of war. Ample means are forthcoming for the preliminary operations, and these are being actively pushed forward. Contracts of considerable magnitude have been entered into for constructing the Colon end of the Canal, a large stock of contractor's plant is being accumulated at various points, and M. de Lesseps assures the shareholders that within the next seven years his scheme will have become an accomplished fact. He contends that the physical difficulties of the undertaking have been greatly exaggerated, that much of what was supposed to be hard rock is found to be soft earth, that the climate is not unhealthy, and that the tradition which places the bones of a Chinamen beneath every sleeper on the

Panama Railway is all idle nonsense. Of course, some allowance must be made for the naturally roseate views and statements of those who have to induce capitalists to advance the sum of £24,000,000 which the Canal is to cost; but when this has been done there seems to be no ground for regarding the scheme as other than feasibie, or for supposing that the completion of the work is a question too remote to call for serious consideration at the present time.

The practicability of M. de Lesseps' scheme is not, however, the question with which this country is immediately concerned. A more serious matter for consideration is to be found in the extraordinary pretensions which have been put forward by the Government of the United States with regard to the control of the Canal when the work has been completed. Certainly these have assumed a somewhat more moderate tone during the last twelve months; but, so far as we can judge from the correspondence which has thus far been made public, the subject is one on which the views of the two Governments are still widely divergent. As a diplomatist Mr. Frelinghuysen is considerably in advance of Mr. Blaine. The tone of this gentleman's remarkable dispatch of June, 1881, can hardly be termed conciliatory, or be regarded as likely to lead to a satisfactory solution of a difficult and debatable question. To open the ball by talking in grandiose style of the possessions of the United States on the Pacific coast "Imperial in extent and extraordinary in growth"—to completely ignore the Clayton-Bulwer Treaty of 1850, which gave England a voice in the question of an interoceanic canal, and to say that for her to attempt to supplement the treaty made in 1846 between the United States and Colombia (formerly New Granada) would necessarily be regarded as "an uncalled-for intrusion," and that any step taken by the European Powers for the purpose of guaranteeing the neutrality of the Canal would be deemed to possess "the nature of an alliance against the United States," was perhaps not the best way of laying the foundation for a mutual and harmonious undertaking. At the time of composing this dispatch Mr. Blaine seems to have been unaware of the existence of the Clayton-Bulwer Treaty. He subsequently became better informed, and both he and his successor in office have addressed themselves to the task of showing the advisability—or rather of pointing out, from the American point of view, the necessity of setting the provisions of this Convention on one side. In November last, Mr. Blaine stated that his Government would not "consent to perpetuate any treaty impeaching its rightful and long-established claim to priority on the American Continent," and that they regarded "the canal question as solely an American one." Mr. Frelinghuysen has adopted a somewhat less defiant tone, and has endeavored to show that the United States are warranted, by principles of justice as well as by those of expediency, in insisting on the abrogation of the Clayton-Bulwer compact. He contends that England has infringed the contract in question by colonizing Belize in opposition to the agreement that neither party should colonize or fortify in the locality and that, since England has seen fit to set this condition on one side, the United States are fully warranted in regarding the Treaty as altogether void. He further maintains that the arrangement in which England took part in 1850 was made with a view to the possible construction of a Canal by the Nicaragua route, and not by way of Panama, whilst the United States, by virtue of the Treaty with Colombia, guaranteed the route of the Panama Railway from sea to sea. Mr. Frelinghuysen states that,

"Should Her Majesty's Government, after obtaining the consent thereto of the States of Colombia, claim under the Clayton-Bulwer Treaty the right to join the States in the protection of the existing Panama Railway, or any future Panama Canal, the United States would submit that experience has shown that no such joint protectorate is requisite, and that the Clayton-Bulwer Treaty is subject to the provisions of the Treaty of 1846 with New Granada while it exists, which Treaty obliges the United States to afford, and secures to it the sole protectorate of any transit by the Panama route. If Great Britain still claimed the right to join in the protectorate, the United States would then determine whether the Treaty stipulations

proposed by Great Britain regulating that joint protectorate, were just; and if so, whether the length of time during which Great Britain has recognized the protectorate of the States in Panama under the Treaty with New Granada, has, or has not, relieved the United States from any obligation to accept a proposal from that Government to join in a guarantee."

* * * * * * *

"The United States esteem themselves competent to refuse to afford their protection jointly with Great Britain, to any other Company than that possessing the original grant from Nicaragua; and they hold themselves free hereafter to protect any interoceanic communication in which they or their citizens may become interested, in such a way as the treaties with local Sovereign Powers may warrant and their interests may require."

There can be no question that Mr. Frelinghuysen is conducting his country's case with much greater skill than was displayed by his predecessor; but the gist of his argument, like that of Mr. Blaine's, amounts simply to the contention that the United States regard the Panama Canal question as one exclusively their own, and that, whatever past Treaties may say on the subject, they do not intend to allow any European Power to have a voice in its future control. The United States cannot think of trusting to any general guarantee of neutrality, but a guarantee by themselves and Colombia is, we are told, an entirely different affair.

That the Clayton-Bulwer Treaty gives England a direct claim to share in the protectorate of the Canal must be plain to any man who understands the English language. But England's claim to consideration in the matter does not rest solely on the wording of the Clayton-Bulwer convention. The value of most treaties is much more apparent than real. They usually retain their efficacy only so long as both the contracting parties are willing to abide by them, and it would seem that the case in point forms no exception to the general rule. However, in discussing the issue now at stake, the English Government can afford to leave past arrangements out of the question, if necessary, and base their claim, as the United States seem inclined to do, on the ground of present right and expediency. The States Government appear to think that the extent of their possessions on the Pacific coast warrants them in claiming the entire control of the Panama route, but England is not altogether unjustified in urging considerations of this kind as reasons why she should have a voice in the matter. She too has possessions of considerable importance at various points on the shores of the Pacific and Indian Oceans, and, what is of less consequence, so far as the Panama route is concerned, it is quite certain that if the Canal were completed, the proportion of British to United States tonnage which would pass through would be about three or four to one.

There are several reasons why the United States should wish to have the complete management of the Panama Canal. As a matter of fact the whole scheme seems to be viewed with a certain amount of disfavor by the Eastern and more influential States of the Union. They are naturally unwilling to encourage the construction of a work that threatens to divert a considerable portion of the traffic now passing through their midst, and at the same time to increase the importance of the Western States; and if the completion of the Canal depended on their good wishes, the world would probably have to wait a long time before the American Continent would be cut in two. Of course, these are considerations which cannot be openly avowed, but as there are occasionally wheels within wheels in American politics, it may be that there exists a party who are doing their best to swamp the entire scheme by political embarrassment. This, however, is a phase of the question which we need not pause to discuss. The arguments the English Foreign Office have to meet are of a totally different class. The United States Government contend that England's maritime supremacy would render her mistress of the situation, and they wish to correct this by taking prior possession of what they think would be a point of great strategic importance in time of war. They contend, moreover, that, even in time of peace, the possession of the Canal would justify them in keeping their naval armament upon a much less extensive scale than would be requisite under a general guarantee of neutrality,

and they do not wish to see created any pretext under which European navies could assemble in American waters. The people of the United States seem inclined to cherish the belief that their right to decide all questions of any political importance relating to any portion of the American Continent is plain and indefeasible, and in the claims put forward with respect to the Panama Canal this belief has taken a precise and definite form. It remains to be seen to what extent this impression can be removed, but it must be admitted that, at the present time, the aspect of affairs is somewhat foreboding.

On the grounds of reason and justice the European Powers may reasonably urge that the question is one in which they may ask to be heard. As a matter of right the United States would be as much justified in attempting to control the traffic around Cape Horn as in taking upon themselves the sole management of the Panama route. Their commercial interests in the latter are not involved more deeply than are those of England. Indeed, it would not be difficult to show that the case is exactly the reverse. The commercial and direct value to any nation of a waterway through the Isthmus would clearly be in proportion to its maritime carrying trade, and in this respect England may fairly claim priority. And, even on political grounds, her stake in the question is not less important than that of the United States. England also has possessions—to use Mr. Blaine's words—"Imperial in extent," if not extraordinary in growth; and to some of these the Panama Canal would be a direct route. Why, therefore, is she to be debarred from taking any part in the matter? If the United States are unwilling to trust any portion of their political interests to a general guarantee of neutrality, surely England is justified in declining to place her interests in the sole keeping of the United States.

It is difficult to reconcile the claims recently put forward by the present representatives of the American Government, with the language adopted by those of their predecessors who took any part in dealing with the Panama question. The latter always maintained that the United States by no means wished to usurp any undue advantage with regard to the proposed waterway, and that their main object was to secure similar and equitable treatment for all. Now this has all been changed and, if we may judge from the tone of the published dispatches, it seems as though the States have fully determined to take possesion of the Canal when made, and to set at nought all claims for consideration coming from this side of the Atlantic. The assertion of the rights of the European Powers will, of course, devolve almost entirely upon this country, and although the American dispatches upon the subject have been addressed to all the principal European States, they are really intended for England only. The results of the Conference which the United States Government proposed should be held between their own representatives, and those of the Central and South American Republics have not yet been made known, but no doubt they will prove quite satisfactory at Washington—much more so, indeed, than they will probably be found in London and Paris. It is perfectly natural that the people of the United States should feel a deep interest in the question of the Panama Canal, but they can hardly expect England to sit quietly by while her stake in the matter is being settled by their Government in conference with the agents of two or three insignificant American Republics. Nor can it be allowed that they have any sufficient reason for objecting to a guarantee of neutrality in which the European Powers generally would take part. We imagine that, if three-fourths of the tonnage passing through the Suez Canal belonged to the United States, they would wish to take at least some part in any guarantee that might be formed with respect to its neutrality. If England possessed no mercantile navy of any of any importance, they would naturally and reasonably object to a proposal that she should shut them quite out of the question, and make an Anglo-Egyptian treaty, which would permit her to seize the Canal and fortify its banks. And this is precisely the position in which we are placed with respect to the Panama route. England asks for no pre-eminence in the matter. All she requires is equitable treatment, and unless the American Government have fully determined to set considerations of right and justice totally on one side, it is difficult to see how this can be refused.

DYNAMO-ELECTRIC MACHINERY.

By PROFESSOR SILVANUS P. THOMPSON, B. A., D. Sc., M. S. T. E.

From the "Journal of the Society of Arts."

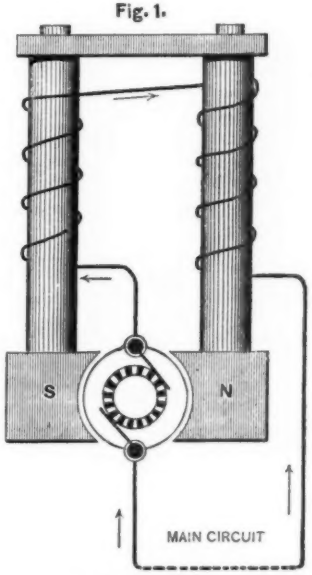
I.

The Dynamo in Theory.

By "Dynamo-electric Machinery," in the most geneneral etymological sense of the term, is meant machinery for converting the energy of mechanical motion into the energy of electric currents, or *vice versa*. From this wide defininition must be excepted machines like the well-known statical induction-machine of Holtz, whose action is purely electrostatic. Those machines only are included in the definition whose action is dependent on the principle of electro-magnetic induction, discovered by Faraday, in 1831. It is, however, not quite easy to decide what machines shall be called dynamo-electric machines, because the sense in which the term is used commonly is narrow, and restricted in a manner not quite logical.

The name dynamo-electric machine appears to have been first employed by Dr. Werner Siemens, in his communication of January 17th, 1867, to the Berlin Academy, in which he described a machine for generating electric currents by the application of mechanical power, the currents being induced in the coils of a rotating armature by the action of electro-magnets, which were themselves excited by the currents so generated. The machine was, in fact, a self-exciting dynamo, with the field magnets and armature united "in series" to the external circuit, or what we now call a "series-dynamo," a diagramatic representation of which is given in Fig. I. But the term dynamo-electric machine, then introduced into electric technology, has not remained thus restrained to its narrowest meaning. It was next applied to machines of kindred nature, in which, though self-excited, only a portion of the entire current generated by the rotating armature was applied to excite the field-magnets (see Fig. 2). This principle of working (now known as that of the "shunt-dynamo"), first introduced by Wheatstone, is but a variation of the former arrangement in detail, and no violence is done to the original term to apply it to both cases. In fact, the name was welcomed as being convenient in practice for distinguishing such machines from those which were not self-excited—those in which either steel magnets or separately excited electro-magnets were used to produce the magnetic field.

Fig. 1.

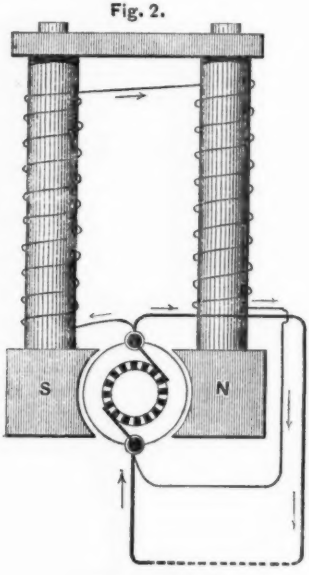


THE SERIES DYNAMO.

But since the great development of electric lighting took place, it has been found convenient to use generating machines in certain combinations, in which the self-exciting principle is abandoned. Some systems of electric lights require alternating currents, produced in machines which cannot excite their own magnets with a continuous magnetization: and there are other systems where

continuous currents are employed, in which also practice has shown that the currents are better regulated when the magnets of the dynamos are separately excited by currents derived from an external source. There is, then, a third class of dynamo-electric machine, the "separately-excited dynamo" (Fig. 3), which was indeed earlier than either of the preceding, having been brought out by Wilde in 1866. A dynamo is a dynamo in fact, whether its magnets be excited by the whole of its own current, or by a part of its own current or by a

Fig. 2.

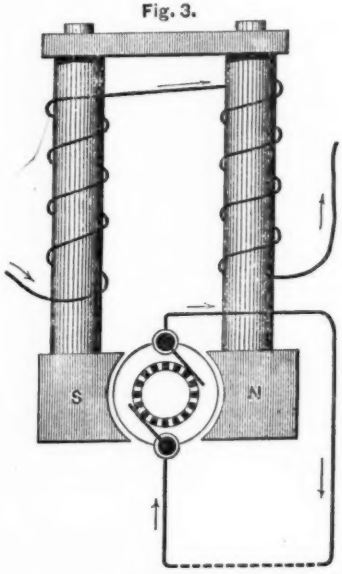


THE SHUNT DYNAMO.

current from an independent source. The source of the magnetizing power is indifferent, provided a magnetic "field" of sufficient intensity be produced wherein the generating coils can be rotated. Now, as it does not matter where the magnetizing power comes from, it is clear that we must include amongst possible sources the power of permanent steel magnets. In short, the arbitrary distinction between so-called magneto-electric mechines (see Fig. 4) and dynamo-electric machines fails when examined carefully. In all these machines a magnet, whether permanently excited, independently excited, or self-excited, is employed to provide a field of magnetic force. And in all of them dynamical power is employed to do the work of rotating the coils of the armature, in order to generate the electric currents.

The true and comprehensive definition of a dynamo-electric machine, is then, the following: A dynamo-electric machine is a machine for converting energy in the form of dynamical power into energy in the form of electric currents, by the operation of setting conductors (usually in

Fig. 3.



THE SEPARATELY-EXCITED DYNAMO.

the form of coils of copper wire) to rotate in a magnetic field.

Inasmuch, however, as every dynamo-electric machine, in the most general sense of the term as now laid down, will work as a motor, and becomes a source of mechanical power when supplied with electric currents, it is possible to discuss dynamo-electric machinery from the opposite points of view in serving the two converse functions, in short, to treat the dynamo on the one hand as a generator, on the other hand as a motor.

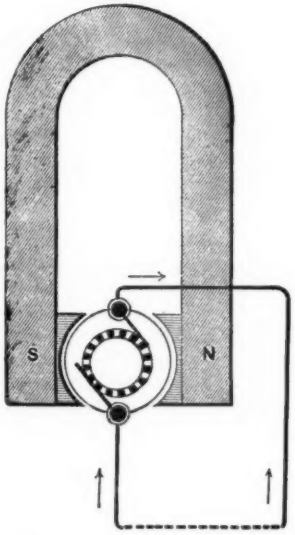
It is as a generator only that the action

of the dynamo will be considered in the first two of these lectures, reserving considerations respecting its functions as a motor for the third lecture of the present course.

The Dynamo in Theory.

To treat exhaustively the theory of dynamo-electric machines, would require not one lecture, but many. It would be necessary, moreover, to enter upon lengthy mathematical and geometrical discussions, which would be out of place in the present course, which is expected to deal with subjects from an industrial, rather than from a purely scientific aspect. The mathematical theory of the dynamo is, indeed, very complex, and takes different forms for its expression in the four classes of machine now included under the one name of "dynamo." For every different variety in each of these classes, there is a fresh variety of mathematical symbols. The theory of alternate current machines is entirely different from that of machines which are to furnish continuous and constant currents. Every form of armature and coils requires its own specific treatment in symbols; and the simple consideration of putting iron cores into the coils, when treated mathematically, introduces such complex expressions as to yield no hopes of a satisfactory general solution.

Fig. 4.



THE MAGNETO DYNAMO.

The theory of the dynamo, then, which will be developed in the present lecture, will not be a general mathematical theory. The aim will be to deal with physical and experimental rather than mathematical ideas. A physical theory of the dynamo is not new, though none of great completeness has yet been given,* most of such explanations being devoted to single machines of some particular type.

It will here be my aim to develop a general physical theory, applicable to all the varied types of dynamo-electric machines, and to trace it out into a number of corollaries, bearing upon the construction of such machines. Having recited these consequences, which we shall deduce from theory, it will then remain to see how these consequences are verified and embodied in the various forms assumed by the dynamo in practice.

Physical Theory of Dynamo-Electric Machines.

All dynamos are based upon the discovery made by Faraday in 1831, that electric currents are generated in conductors by moving them in a magnetic field. Faraday's principle may be enunciated as follows: When a conductor is moved in a field of magnetic force in any way so as to cut the lines of force, there is an electromotive force produced in the conductor, in a direction at right angles to the direction of the motion,† and at right

* See Du Moncel ("Exposé des Applications de l'Electricité," vol. ii.); Niaudet, "Machines Electriques;" Schellen, "Die Magnet-und Dynamo-elektrischen Maschinen;" Antoine Breguet (see "Annales de Chimie et de Physique," 1879). See also some theoretical papers by Clerk Maxwell in "Philosophical Magazine," 1867, and by MM. Marcel Deprez, Cabanellas, de Gourant, and others in the "Comptes Rendus;" also sundry papers by Frölich, Werner Siemens, Hagenbach, and others in the "Elektrotechnische Zeitschrift" and other German publications. Of more general scope is the physical theory advanced by the late M. Antoine Breguet, which deals with dyamos of the Gramme and Siemens type, and of which a detailed summary is given in "Electric Illumination." In an introductory chapter of the same work I have endeavored to lay the foundation of a more general physical throry. An admirable series of papers on the mathematical theory of dynamo-electric machines, from the pen of a well-known professor of physics, is at present appearing in the columns of *The Electrician*.

† Or, more strictly, to the resolved part of the motion in a plane perpendicular to the lines of force.

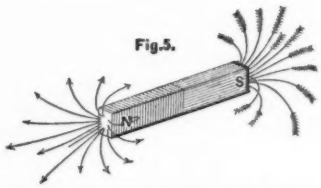
angles also to the direction of the lines of force, and to the right of the lines of force, as viewed from the point from which the motion originates.*

This induced electromotive force is, as Faraday showed, proportional to the number of lines of magnetic force cut per second; and is, therefore, proportional to the intensity of the magnetic "field," and to the length and velocity of the moving conductor. For steady currents, the flow of electricity in the conductor is, by Ohm's well-known law, directly proportional to this electromotive force, and inversely proportional to the resistance of the conductor. For sudden currents, or currents whose strength is varying rapidly, this is no longer true. And it is one of the most important matters, though one too often overlooked in the construction of dynamo-electric machinery, that the "resistance" of a coil of wire, or of a circuit, is by no means the only obstacle offered to the generation of a momentary current in that coil or circuit; but that, on the contrary, the self-induction exercised by one part of a coil or circuit upon another part or parts of the same, is, in many cases, quite as important a consideration, and in some cases a more important consideration, than the resistance.

To understand clearly Faraday's principle—that is to say, how it is that the act of moving a wire so as to cut magnetic lines of force can generate a current of electricity in that wire—let us inquire what a current of electricity is.

A wire through which a current of electricity is flowing looks no different from any other wire. No man has ever yet seen the electricity running along in a wire, or knows precisely what is happening there. Indeed, it is still a disputed point which way the electricity flows, or whether or not there are two currents flowing simultaneously in opposite directions. Until we know absolutely certainly what electricity is, we cannot expect to know precisely what a current of electricity is. But no electrician is in any doubt as to one most vital matter, namely, that when an electric current flows through a wire, the magnetic forces with which that wire is thereby, for the time, endowed, reside not in the wire at all, but in the space surrounding it. Every one knows that the space or "field" surrounding a magnet is full of magnetic "lines of force," and that these lines run

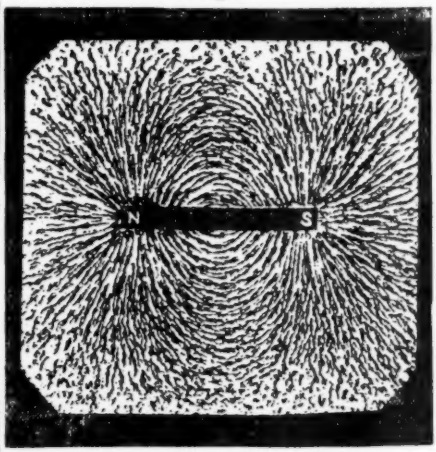
Fig.5.



LINES OF FORCE OF BAR-MAGNET.

in tufts (Fig. 5) from the N-pointing pole to the S-pointing pole of the magnet, invisible until revealed by dusting iron filings into the field, whereby their presence is made known, though they

Fig.6.



MAGNETIC FIELD OF BAR-MAGNET.

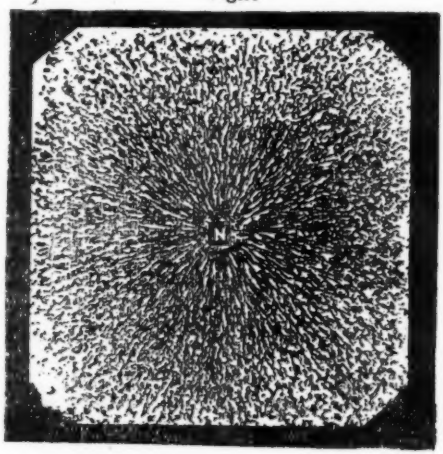
are always in reality there (Fig. 6). A view of the magnetic field at the pole of a bar-magnet, as seen end-on, would of course exhibit merely radial lines, as in Fig. 7.

Now, every electric current (so-called) is surrounded by a magnetic field, the

* A more usual rule for remembering the direction of the induced currents is the following adaptation from Ampère's well-known rule: Supposing a figure swimming in any conductor to turn so as to look along the (positive direction of the) lines of force. Then, if he and the conductor be moved towards his right hand, he will be swimming with the current induced by this motion.

lines of which can be similarly revealed. To observe them, a hole is bored through a card or a piece of glass, and the wire

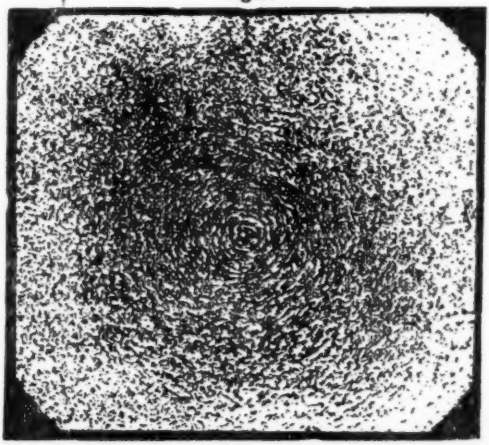
Fig.7.



MAGNETIC FIELD ROUND ONE POLE, END-ON.

which carries the current must be passed up through the hole. When iron filings are dusted into the field they assume the

Fig.8.



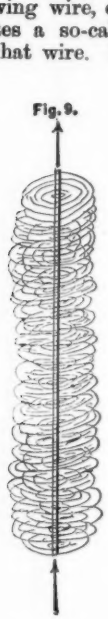
MAGNETIC FIELD SURROUNDING CURRENT. THE CONDUCTING WIRE SEEN END-ON.

form of concentric circles (Fig. 8), showing that the lines of force run completely round the wire, and do not stand out in tufts. In fact, every conducting wire is surrounded by a sort of magnetic whirl, like that shown in Fig. 9. A great part of the energy of the so-called electric current in the wire consists in these external magnetic whirls. To set them up requires an expenditure of energy; and to maintain them requires also a constant expenditure of energy. It is these mag-

netic whirls which act on magnets, and cause them to set as galvanometer needles do, at right angles to the conducting wire.

Now, Faraday's principle is nothing more nor less than this: That by moving a wire near a magnet, across a space in which there are magnetic lines, the motion of the wire, as it cuts across those magnetic lines, sets up magnetic whirls round the moving wire, or, in other language, generates a so-called current of electricity in that wire. Poking a mag-

Fig. 9.

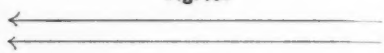


MAGNETIC WHIRL SURROUNDING WIRE CARRYING CURRENT.

net-pole into a loop or circuit of wire also necessarily generates a momentary current in the wire loop, because it momentarily sets up magnetic whirls. In Faraday's language, this action increases the number of magnetic lines of force intercepted by the circuit.

It is, however, necessary that the moving conductor should, in its motion, so cut the lines of force as to alter the number of lines of force that pass through the circuit of which the moving conductor forms part. If a conducting circuit —a wire ring or single coil, for example —be moved along in a uniform magnetic field, as indicated in Fig. 10, so that only the same lines of force pass through it, no current will be generated. Or, if again, as in Fig. 11, the coil be moved, by a motion of translation, to another part of the uniform field, as many lines of force will be left behind as are gained in advancing

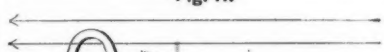
Fig. 10.



CIRCUIT MOVED WITHOUT CUTTING LINES OF FORCE OF UNIFORM MAGNETIC FIELD.

from its first to its second position, and there will be no current generated in the coil. If the coil be merely rotated on itself round a central axis, like the rim of a fly-wheel, it will not cut any more lines of force than before, and this motion will

Fig. 11.



CIRCUIT MOVED WITHOUT CUTTING ANY MORE LINES OF FORCE.

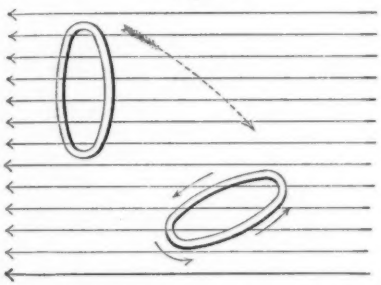
generate no current. But if, as in Fig. 12, the coil be tilted in its motion across the uniform field, or rotated round any axis in its own plane, then the number of lines of force that traverse it will be altered, and currents will be generated. These currents will flow round the ring-coil in the positive* sense (as viewed

* The positive sense of motion round a circle is that opposite to the sense in which the hands of a clock go round.

from the point toward which the lines of force run), if the effect of the movement is to diminish the number of lines of force that cross the coil; they will flow round in the opposite sense, if the effect of the movement is to increase the number of intercepted lines of force.

If the field of force be not a uniform one, then the effect of taking the coil, by a simple motion of translation, from a place where the lines of force are dense to a place where they are less dense, as from position 1 to position 2 in Fig. 13, will be to generate currents. Or, if the motion be to a place where the lines of force run in the reverse direction, the effect will be the same, but even more powerful.

Fig. 12.



CIRCUIT MOVED SO AS TO ALTER NUMBER OF LINES OF FORCE THROUGH IT.

We may now summarize the points under consideration, and some of their immediate consequences, in the following manner:

(1.) A part, at least, of the energy of an electric current exists in the form of magnetic whirls in the space surrounding the conductor.

(2.) Currents can be generated in conductors by setting up magnetic whirls round them.

(3.) We can set up magnetic whirls in conductors by moving magnets near them, or moving them near magnets.

(4.) To set up and maintain such magnetic whirls uses up a continuous expenditure of energy, or, in other words, consumes power.

(5.) To induce currents in a conductor, there must be relative motion between conductor and magnet of such a kind as to alter the number of lines of force embraced in the circuit.

(6.) Increase in the number of lines of force embraced by the circuit produces a current in the opposite sense to decrease.

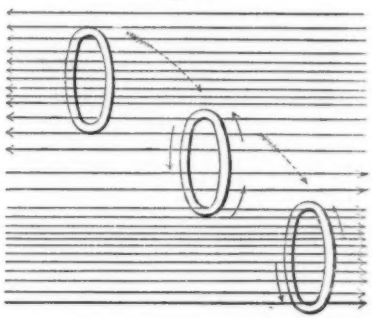
(7.) Approach induces an electromotive force in the opposite direction to that induced by recession.

(8.) The more powerful the magnet pole or magnetic field, the stronger will be the current generated (other things being equal).

(9.) The more rapid the motion, the stronger will be the currents.

(10.) The greater the length of the moving conductor thus employed in cut-

Fig. 13.



MOTION OF CIRCUIT IN NON-UNIFORM MAGNETIC FIELD.

ting lines of force (*i e.*, the longer the bars, or the more numerous the turns of the coil), the stronger will be the currents generated.

(11.) The shorter the length of those parts of the conductor not so employed, the stronger will be the current.

(12.) Approach being a finite process, the method of approach and recession (of a coil towards and from a magnet-pole) must necessarily yield currents alternating in direction.

(13.) By using a suitable commutator, all the currents, direct or inverse, produced during recession or approach, can be turned into the same direction in the wire that goes to supply currents to the external circuits, thereby yielding an almost uniform current.

(14.) In a circuit where the flow of

currents is steady* it makes no difference what kind of magnets are used to procure the requisite magnetic field, whether permanent steel magnets or electro-magnets, self-excited or otherwise.

(15.) Hence the current of the generator may be itself utilized to excite the magnetism of the field-magnets, by being caused, wholly or partially, to flow round the field magnet coils.

A very large number of dynamo-electric machines have been constructed upon the foregoing principles. The variety is indeed so great, that classification is not altogether easy. Some have attempted to classify dynamos according to certain constructional points, such as whether the machine did or did not contain iron in its moving parts (which is a mere accident of manufacture, since almost all dynamos will work either with or without iron in their armatures, though not equally well); or whether the currents generated were direct and continuous, or alternating (which is in many cases a mere question of arrangement of parts of the commutator or collectors); or what was the form of the rotating armature (which is, again, a matter of choice in construction, rather than of fundamental principle). The classification which I shall adopt, is one which I have found more satisfactory and fundamental than any other. I distinguish three genera or main classes of dynamos.

Class I.—Dynamos in which there is rotation of a coil or coils in a uniform† field of force, such rotation being effected (as in the manner indicated in Fig. 12), round an axis in the plane of the coil, or one parallel to such an axis.

EXAMPLES.—Gramme, Siemens (Alteneck), Edison, Lontin, Bürgin, Fein, Schückert, Jürgensen (Thomson's Mousemill-dynamo), [Brush].

Class II.—Dynamos in which there is translation* of coils to different parts of a complex field of varying strength, or of opposite sign. Most, but by no means all, of the machines of this class furnish alternate currents.

EXAMPLES.—Pixii, Clarke, Niaudet, Wallace-Farmer, Wilde (alternate), Siemens (alternate), Hopkinson and Muirhead, Thomson (alternate), Gordon (alternate), Siemens-Alteneck (Disk Dynamo), Edison (Disk Dynamo), De Meritens.

Class III.—Dynamos having a conductor rotating so as to produce a continuous increase in the number of lines of force cut, by the device of sliding one part of the conductor on or round the magnet, or on some other part of the circuit.

EXAMPLES.—Faraday's Disk-machine, Siemens's ("Unipolar" Dynamo), Voice's Dynamo.

One machine, and one only, am I aware of which does not fall exactly within any of these classes,† and that is the extraordinary tentative dynamo of Edison, in which the coils are waved to and fro at the ends of a gigantic tuning-fork, instead of being rotated on a spindle.

Suppose, then, it were determined to construct a dynamo upon any one of these plans—say the first—a very slight acquaintance with Faraday's principle and its corollaries would suggest that, to obtain powerful electric currents, the machine must be constructed upon the following guiding lines:—

(*a.*) The field-magnets should be as strong as possible, and their poles as near together as possible.

(*b.*) The armature should have the greatest possible length of wire upon its coils.

* For currents that are not steady, there are other considerations to be taken into account, as will be shown hereafter.

† Or approximately uniform. A Gramme ring, or a Siemens drum armature, will work in a by no means uniform field, but is adapted to work in a field in which the lines of force run uniformly from one side to the other. But in such a field, a multipolar armature of many coils, such as that of Wilde, or such as is used in the Gramme alternate-current, or in the Siemens alternate-current machine, is useless and out of place. Indeed, the classification almost amounts to saying that in machines of Class I. there is one field of force, while in machines of Class II. there are many fields of force, or the whole field of force is complex.

* The motion by which the individual coils are carried round on such armatures as those of Niaudet, Wallace-Farmer, Siemens (alternate), &c., is, of course, not a pure translation. It may be regarded, however, as a combination of a motion of translation of the coil round the circumference of a circle, with a rotation of the coil round its own axis, which, as we have seen above, has *no* electrical effect. It is, of course, the translation of the coil to different parts of the field which is the effective motion.

† There are a few dynamos, including the Elphinstone Vincent, and the four pole Gülcher, which, though really belonging to the first class, are not named above, because they are, in reality, compound machines. The Gülcher, with its doubled field magnets and four collecting brushes, is really a double machine, though it has but one rotating ring. The same is the case with an octagonal pattern Gramme, which has four brushes. The Elphinstone Vincent machine, a remarkable one in many respects, is a triple machine, having six brushes; and may, indeed, be used as three machines, to feed three separate circuits.

(*c.*) The wire of the armature coils should be as thick as possible, so as to offer little resistance.

(*d.*) A very powerful steam-engine should be used to turn the armature, because,

(*e.*) The speed of rotation should be as great as possible.

Unfortunately, it is impossible to realize all these conditions at once, as they are incompatible with one another; and, moreover, there are a great many additional conditions to be observed in the construction of a successful dynamo. We will deal with the various matters in order, beginning with the speed of the machine.

Relation of Speed to Power.

Theory shows that, if the intensity of the magnetic field be constant, the electromotive force should be proportioned to the speed of the machine. Numerous experiments, by many different workers, have shown that this is true, within certain limits, for those machines in which the field magnets are independent of the main circuit, that is to say, for magneto and separately excited dynamos. It is not, however, quite exact unless the resistance of the circuit be increased proportionately to the speed, because the current in the coils itself re-acts on the magnetic field, and alters the distribution of the lines of force. The consequence of this reaction is that, firstly, the position of the "diameter of commutation" is altered; and, secondly, the effective number of lines of force is reduced. So that, with a constant resistance in circuit, the electromotive force, and therefore the current, are slightly less at high speeds than the proportion of the velocities would lead one to expect. Since the product of current into electromotive force gives a number proportional to the electric work of the machine, it follows that, for "independently excited" machines, the electric work done in given time is nearly proportional to the square of the speed, and the work drawn from the steam-engine will be similarly proportional to the square of the speed.

In self-exciting machines, whether "series" or "shunt" in their arrangements, a wholly different law obtains. If the iron of the field-magnets be not magnetized near to saturation, then, since the increase of current consequent on increase of speed produces a nearly proportional increase in the strength of the magnetic field, this increase will re-act on the electromotive force, and cause it to be proportional more nearly to the square of the velocity, which again will cause the current to increase in like proportion. But since the magnetization of the iron is, even when far from saturation point, not exactly proportional to the magnetizing force, but something less, it is in practice found that the electric work of the machine is not proportional to the fourth power of the speed, is not even proportional to the third power of the speed, but to something slightly less than the latter.

As mechanical considerations forbid too high a velocity in the moving parts, it is clear that, if there be a limiting speed at which it is safe to run any given armature, the greatest amount of work will be done at that speed by using the most powerful magnets possible, namely, electro-magnets rather than magnets of steel.

Marcel Deprez has shown* that it is convenient to study the action of dynamos, by constructing a curve which he calls a "characteristic," showing, for any given speed, the relation between electromotive force and strength of current generated in a circuit of given resistance. Amongst other conclusions, M. Deprez has found that for every dynamo there is a certain speed which we may call the "critical speed," at which, no matter what the current is which circulates in the coils of the field magnets, the electromotive force is proportional to the strength of that current; and he bases upon the discovery of this critical speed two methods of utmost importance in practice, for obtaining, automatically, either a constant electromotive force or a constant current at will, in a circuit in which the resistances are varied to any degree.

In all these combinations, however, everything depends upon the condition that the driving speed shall be uniform. For all the best kind of electric work, a gas-engine is wholly out of the question as a source of power, because of its extreme inequalities in speed. Even with

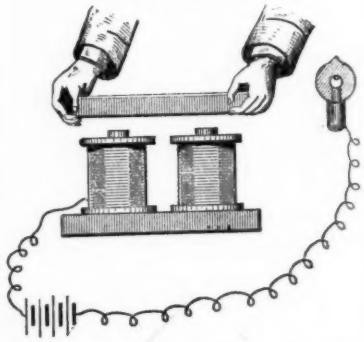
* *Comptes Rendus*, 1881, and elsewhere. For an excellent summary of the work of M. Deprez, see *La Lumiere Electrique*, February 18, 1882.

the best steam-engines, a specially sensitive valve is required; and probably such valves will, in the future, be operated electrically by self-acting electro-magnet gearing. In any case, where the driving is at all liable to be uneven, the obvious and simple precaution should be taken of placing a heavy fly-wheel on the axis of the dynamo. It is, indeed, singular that this is not more generally done.

Field-magnets

The coils of the field-magnets of a dynamo cannot be constructed of no resistance. They, therefore, always waste some of the energy of the currents in heat. It has, therefore, been argued that it cannot be economical to use electro-magnets in comparison with permanent magnets of steel, which have only to be magnetized once for all. Nevertheless, there are certain considerations which tell in favor of electro-magnets. For equal power, their prime cost is less than that of steel magnets, which, moreover, are not permanent, but require remagnetizing at intervals. Moreover, as we have seen, from the fact that there is a limiting velocity at which it is safe to run a machine, it is important, in order not to have machines of needlessly great size, to use the most powerful field-magnets possible. But if we do not get our magnetism for nothing, and find it more convenient to spend part of our current upon the electro-magnets, economy dictates that we should so construct them that their magnetism may cost us as little as possible. To magnetize a piece of iron requires the expenditure of energy; but when once it is magnetized, it requires no further expenditure of energy (save the slight loss by heating in the coils, which may be reduced by making the resistance of the coils as little as possible) to keep it so magnetized, provided the magnet is doing no work. Even if it be doing no work, if the current flowing round it be not steady, there will be loss. If it do work, say in attracting a piece of iron to it, then there is an immediate and corresponding call upon the strength of the current in the coils, to provide the needful energy. This point may be illustrated by the following experiment:—Let a current from a steady source (see Fig. 14) pass through an incandescent lamp, and also through an electro-magnet, whose cores it magnetizes. When once established, the current is perfectly steady, and none of its energy is wasted on the magnet (save the negligible trifle due to the resistance of the coils). But if now the magnet is allowed to do work in attracting an iron bar towards itself, the light of the lamp is seen momentarily to fade. When the iron bar is snatched away, the light exhibits a momentary increase; in each case resuming its original intensity when the motion ceases. Now, in a dynamo where, in many cases there are revolving parts containing iron, it is

Fig. 14.



REACTION OF MOVING MASS OF IRON ON AN ELECTRO-MAGNET.

of importance that the approach of a recession of the iron parts should not produce such reactions as these in the magnetism of the magnet. Large, slow-acting field-magnets are therefore advisable. The following points embody the conditions for attaining the end desired.

(*a.*) The body of the field-magnets should be solid. Even in the iron itself currents are induced, and circulate round and round whenever the strength of the magnetism is altered. These self-induced currents tend to retard all changes in the degree of magnetization. They are stronger in proportion to the square of the diameter of the magnet, if cylindrical or to its area of cross-section. A thick magnet will, therefore, be a slow-acting one, and will steady the current induced in its field.

(*b.*) Use magnets having in them plenty of iron. It is important to have a suffi-

cient mass, that saturation may not be too soon attained.

(*c.*) Use the softest possible iron for field-magnets, not because soft iron magnetizes and demagnetizes quicker than other iron (that is here no advantage); but because soft iron has a higher magnetic susceptibility than other iron—is not so soon saturated.

(*d.*) Use long magnets. Again, the use of long magnets is to steady the magnetism, and therefore to steady the current. A long magnet takes a longer time than a short magnet to magnetize and demagnetize. It costs more than a short magnet, it is true, and requires more copper wire in the exterior coil; but the copper wire may be made thicker in proportion, and will offer less resistance. The magnetism so obtained should be utilized as directly as possible, therefore

(*e.*) Place the field-magnets or their pole-pieces as close to the rotating armature as is compatible with safety in running.

(*f.*) Avoid edges and corners on the magnets and pole-pieces if you want a uniform field. The laws of distribution of the magnetic lines of force round a pole are strikingly akin to those of the distribution of electrification over a conductor. We avoid edges and points in the latter case, and ought to do in the former. If the field-magnets or their pole-pieces have sharp edges, the field cannot be uniform, and some of the lines of force will run uselessly through the space outside the armature instead of going through it. Theoretically, the very best form to give externally to a magnet is that of the curves of the magnetic lines of force.

(*g.*) Reinforce the magnetic field by placing iron, or better still, electro-magnets, within the rotating armature. In many cases this is done by giving the armature coils iron cores which rotate with them; in other cases, the iron cores or internal masses are stationary. In the former case there is loss by heating; in the latter, there are structural difficulties to be overcome. Siemens has employed a stationary mass within his rotating drum-armature. Internal electro-magnets serving the function of concentrating the magnetism of the field, and of so providing a continuous magnetic circuit, have been used by Lord Elphinstone and Mr. Vincent. A similar device obtains in Sir. W. Thomson's "mouse-mill" dynamo, and in Jürgensen's dynamo.

(*h.*) In cases where a uniform magnetic-field is not desired, but where, as in dynamos of the second class, the field must have varying intensity at different points, it may be advisable specially to use field-magnets with edges or points, so as to concentrate the field at certain regions.

Pole-pieces.

(*i.*) The pole-pieces should be heavy, with plenty of iron in them, for reasons similar to those urged above.

(*j.*) The pole-pieces should be of shapes really adapted to their functions. If intended to form a single approximately uniform field, they should not extend too far on each side. The distribution of the electromotive force in the various sections of the coils on the armature depends very greatly on the shape of the pole-pieces.

(*k.*) Pole-pieces should be constructed so as to avoid, if possible, the generation in them of useless Foucault currents. The only way of diminishing loss from this source is to construct them of laminæ, built up so that the mass of iron is divided by planes in a direction perpendicular to the direction of the currents, or of the electromotive forces tending to start such currents.

(*l.*) If the bed-plates of dynamos are of cast-iron, care should be taken that these bed-plates do not short-circuit the magnetic lines of force from pole to pole of the field-magnets. Masses of brass, zinc, or other non-magnetic metal may be interposed; but are at best a poor resource. In a well-designed dynamo, there should be no need of such devices.

Field-magnet Coils.

(*m.*) In order to be of the greatest possible service, the coils of the field-magnets should be wound on most thickly at the middle of the magnet, not distributed uniformly along its length, nor yet crowded about its poles. The reason for this is two-fold. Inspection of Fig. 6, will show that many of the lines of force of a magnet "leak out" from the sides of the magnet before reaching its poles, where they should all emerge if the mass

of the magnet were perfectly equally magnetized throughout its whole length. Internally, the magnetization of the magnet is greatest at its center. At, or near the center, therefore, place the magnetizing coils, that the lines of force due to them may run through as much iron as possible. The second reason for not placing the coils at the end is this: any external influence which may disturb the magnetism of a magnet, or affect the distribution of its lines of force, affects the lines of force in the neighborhood of the pole far more than those in any other region. It is for this reason that in Bell's telephones, where it is desired to make a magnet most sensitive to variations in intensity, the coils are fixed on at the pole. In the field-magnet of a dynamo, on the contrary, where the magnet is wanted to be as steady and constant as possible in its magnetic power, the coils should not be placed on the poles.

(*n.*) The proper resistances to give to the field-magnet coils of dynamos have been calculated by Sir Wm. Thomson,* who has given the following results:

For "Series Dynamo," make the resistance of the field magnets a little less than that of the armature. Both of them should be small, compared with the resistance of the external circuit. The ratio of the waste by heating in the machine, to the total electric work of the machine, will be:

$$\frac{\text{waste:}}{\text{total work}} = \frac{R_M + R_A}{R_M + R_A + R_X}$$

and

$$\frac{\text{useful work}}{\text{total work}} = \frac{R_X}{R_M + R_A + R_X}$$

where

R_M is the resistance of the magnets,
R_A " " " armature,
R_X " " " external circuit.

For a "Shunt Dynamo," the rule is different. The best proportions are when such that

$$R_X = \sqrt{R_M R_A},$$

or that

$$R_M = \frac{R_x^2}{R_A};$$

also the ratio of useful work is:

$$\frac{\text{useful work}}{\text{total work}} = \frac{1}{1 + 2\sqrt{\frac{R_A}{R_M}}}.$$

An example of the latter may be of advantage. Suppose it was wished that the waste should not be more than 10 per cent. of the useful work, the ratio of the formula must equal $\frac{10}{11}$, or $1 \div 1\frac{1}{10}$. Hence $\sqrt{\frac{R_A}{R_M}}$ must equal $\frac{1}{20}$; or R_M the resistance of the field magnets must be 400 times R_A that of the armature.

Armature Cores.

(*o.*) Theory dictates that if iron is employed in armatures, it must be slit or laminated, so as to prevent the generation of Foucault currents. Such iron cores should be structurally divided in planes normal to the circuits round which electromotive force is induced; or should be divided in planes parallel to the lines of force and to the direction of the motion. Cores built up of varnished iron wire, or of thin disks of sheet-iron separated by varnish, asbestos paper, or mica, partially realize the required condition.

(*p.*) Armature cores should be so arranged that the direction of polarity of their magnetization is never abrubtly reversed during their rotation. If this precaution is neglected, the cores will be heated.

Armature Coils.

(*q.*) All needless resistance should be avoided in armature coils, as hurtful to the efficiency of the machine. The wires should therefore be as short and as thick as is consistent with obtaining the requisite electromotive force, without requiring an undue speed of driving.

(*r.*) The wire should be of the very best electric conductivity. The conductivity of good copper is so nearly equal to that of silver (over 96 per cent.), that it is not worth while to use silver wires in the armature coils of dynamos.

(*s.*) In cases where rods or strips of copper are used instead of mere wires, care must be taken to avoid Foucault currents by laminating such conductors, or slitting them in planes parallel to the electromotive force, that is to say, in planes per-

* British Association Report, 1881, p. 528.

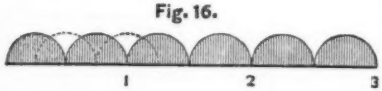
pendicular to the lines of force, and to the direction of the rotation.*

(*t.*) In dynamos of the first class, when used to generate currents in one direction, since the currents generated in the coils are doing half their motion inverse to those generated during the other half of their motion, a commutator or a collector of some kind must be used. In any single coil without a commutator, the alternate currents would be generated in successive revolutions, if the coil were destitute of self-induction currents, whose variations may be graphically expressed by a recurring sinusoidal curve, such as Fig. 15. But if by the addition of a sim-

Fig. 15.

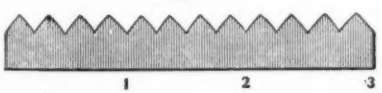
ple split-tube commutator the alternate halves of these currents are reversed, so as to rectify their direction through the rest of the circuit, the resultant currents will not be continuous, but will be of one sign only, as shown in Fig. 16, there be-

Fig. 16.



ing two currents generated during each revolution of the coil. If two coils are used, at right angles to each others' planes, so that one comes into the position of best action. while the other is in the position of least action (one being normal to the lines of force, when the other is parallel to them), and their actions be superposed, the result will be, as shown

Fig. 17.



in Fig. 17, to give a current which is continuous, but not steady, having four slight undulations per revolution. If any number of separate coils are used, and their effects, occurring at regular intervals, be superposed, a similar curve will be obtained, but with summits proportionately more numerous and less elevated. When the number of coils used is very great, and the overlappings of the curves still more complete, the row of summits will form practically a straight line, or the whole current will be practically constant.

(*u.*) The rotating armature coils ought therefore to be divided into a large number of sections, each coming in regular succession into the position of best action.

(*v.*) If these sections, or coils, are independent of each other, each coil, or diametral pair of coils, must have its own commutator. If they are not independent, but are wound on in continuous connection all round the armature, a collector is needed, consisting of parallel metallic bars as numerous as the sections each bar communicating with the end of one section and the beginning of the next.

(*w.*) In any case, the connections of such sections and of the commutators, or collectors, should be symmetrical round the axis; for if not symmetrical, the induction will be unequal in the parts that successively occupy the same positions with respect to the field-magnets, giving rise to inequalities in the electromotive force, sparking at the commutator, or collector, and other irregularities.

(*x.*) In the case where the coils are working in series, it is advantageous to arrange the commutator to cut out the coil that is in the position of least action, as the circuit is thereby relieved of the resistance of an idle coil. But no such coil should be short-circuited to cut it out. In the case where the coils are working in parallel, cutting out an idle coil increases the resistance, but may be advisable to prevent heating from waste currents traversing it from the active coils.

(*y.*) In the case of pole-armatures, the coils should be wound on the poles rather than on the middles of the projecting cores; since the variations in the induced magnetism are most effective at or near the poles. (See § *m.*)

(*z.*) Since it is impossible to reduce the resistance of the armature coils to zero, it is impossible to prevent heat be-

* It will be observed that the rule for eliminating Foucault currents is different, in the three cases, for magnets and their pole-pieces, for moving iron armature cores, and for moving conductors in the armature.

ing developed in those coils during their rotation; hence it is advisable that the coils should be wound with air spaces in some way between them, that they may be cooled by ventilation.

(*aa.*) The insulation of the armature coils should be ensured with particular care, and should be carried out as far as possible with mica and asbestos, or other materials not liable to be melted, if the armature coils become heated.

COMMUTATORS, COLLECTORS, AND BRUSHES.

(*ab.*) Commutators and collectors being liable to be heated through imperfect contract, and liable to be corroded by sparking, should be made of very substantial pieces of copper.

(*ac.*) In the case of a collector made of parallel bars of copper, ranged upon the periphery of a cylinder, the separate bars should be capable of being removable singly, to admit of repairs and examination.

(*ad.*) The brushes should touch the commutator or the collector at the two points, the potentials of which are respectively the highest and the lowest of all the circumference. In a properly and symmetrically built dynamo, these points will be at opposite ends of a diameter.

(*ae.*) In consequence of the armature itself, when traversed by the currents, acting as a magnet, the magnetic lines of force of the field will not run straight across, from pole to pole, of the field magnets, but will take, on the whole, an angular position, being twisted a considerable number of degrees in the direction of the rotation. Hence the diameter of commutation (which is at right-angles to the resultant lines of force in machines of the Siemens and Gramme type, and parallel to the resultant lines of force in machines of the Brush type), will be shifted forward. In other words, the brushes will have a certain angular lead. The amount of this lead depends upon the relation between the intensity of the magnetic field and the strength of the current in the armature. This relation varies in the four different types of field magnets. In the series dynamo, where the one depends directly on the other, the angle of lead is nearly constant, whatever the external resistance. In other forms of dynamo, the lead will not be the same, because the variations of resistance in the external circuit do not produce a proportionate variation between the two variables which determine the angle of lead.

(*af.*) Hence in all dynamos it is advisable to have an adjustment, enabling the brushes to be rotated round the commutator or collector, to the position of the diameter of commutation for the time being. Otherwise there will be sparking at the brushes, and in part of the coils at least the current will be wasting itself by running against an opposing electromotive force.

(*ag.*) The arrangements of the collector, or commutator, should be such that, as the brushes slip from one part to the next, no coil or section in which there is an electromotive force should be short circuited, otherwise work will be lost in heating that coil. For this reason, it is well so to arrange the pole places that the several sections or coils on either side of the neutral position should differ but very slightly in potential from one another.

(*ah.*) The number of contact points between the brushes and the collector, or commutator, should be as numerous as possible, for by increasing the number of contacts, the energy wasted in sparks will be diminished inversely as the square of that number. The brushes might, with advantage, be laminated, or made of parallel loose strips of copper, each bearing edgeways on the collector.

RELATION OF SIZE TO EFFICIENCY.

The efficiency of a dynamo-electric machine is the ratio of the useful electrical work done by the machine to the total mechanical work applied in driving it. Every circumstance which contributes to wasting the energy of the current reduces the efficiency of the machine. In the preceding paragraphs it has been shown what the chief electric sources of waste are, and how they may be avoided. The precautions needful to obviate Foucault currents, to avoid reversals of magnetization, to get rid of needless resistance, to obviate opposing electro motive forces, have been detailed. Mechanical friction of the moving parts can be minimized also by due mechanical arrangements. But one thing cannot be entirely obviated, because even the best conductors employed have a certain resistance. We cannot prevent the heating of the conducting

coils; and the more powerful the current generated by the machine, the more important does this source of waste become. There is but one way to reduce this, and that is by increasing the size of the machines. For some three years or so I have been the advocate of large dynamo machines, not because I have any admiration for mere bigness, but because, as in steam engines so in dynamos, the larger machines may be made more efficient than the small, in proportion to their cost. In discussing the relation of size to efficiency, I shall assume, for the sake of argument, that the size of any machine can be increased n times in every dimension, and that though the dimensions are increased, the velocity of rotation remains the same, and that the intensity of the magnetic field, per square centimeter, remains also constant. If the linear dimensions be n times as great in the larger machine as in the smaller, the area it stands on will be increased n^2 times, and its volume and weight n^3 times. The cost will be less than n^3 times but greater than n times. If the same increase of dimensions in the coils be observed (the number of layers and of turns remaining the same as before), there will be in the armature coils a length n times as great, and the area of cross-section of the wire will be n^2 times as great as before. The resistance of these coils will, therefore, be but $\frac{1}{n}$ part of the original resistance of the smaller machine. If the field-magnet coils are increased similarly they will offer only $\frac{1}{n}$ of the resistance of those of the smaller machine. Moreover, seeing that while the speed of the machine is the same, the area cut through by the rotating coils is increased n^2 times, these coils will in the same time cut n^2 times as many lines of force, or the electromotive force will be increased n^2 times. Supposing the whole of the circuit to be similarly magnified, its resistance will also be but $\frac{1}{n}$ of the previous value.

If the machine is a "series"-wound dynamo, an electromotive force, n^2, working through $\frac{1}{n}$ resistance will give a current n^2 times as great as before. Such a current will, as a matter of fact, much more than suffice to bring the magnetic field to the required strength, viz., n^2 times the area of surface magnetized to the same average intensity per square centimeter, as stipulated; for the mass of iron being n^3 times as great, it need not be so much saturated as before to give the required field. Here an economy may be effected, therefore, by further reducing the number of coils, and therefore the wasteful resistance of the field-magnet coils, in the proportion of n^3 to n^2, or to $\frac{1}{n}$ of its already diminished value.

Even if this were not done, by the formula given above for the electrical efficiency of a "series" dynamo, the waste, when working through a constant external resistance, will be n-fold less than with the smaller machine. Now, if the current be increased n^2 times, and the electromotive force n^2 times, the total electric work which is the product of these will be n^4 times greater than in the small machine, and it will consume n^4 times as much power to drive it.* It is clearly an important economy, if a machine costing less than n^3 times as much, will do n^4 times as much work (to say nothing of the increased ratio of efficiency). A machine doubled in all its linear dimensions will not cost eight times as much, and will be electrically thirty-two times as powerful a machine.

* This calculation agrees with the result deduced on entirely different principles by M. Marcel Deprez. M. Deprez considers the mutual reaction, dF, between two elements, ds and ds', of a system of conductors which, by Ampère's principle, is

$$dF = C^2 \frac{ds\, ds'}{r^2} f(a)$$

where C is the current, r the distance of the elements apart, and $f(a)$ a certain function of the machine, independent of its size. Writing a for the area, we have

$$dF = \frac{C^2}{a^2} \cdot \frac{ada \cdot ada'}{r^2} \cdot f(a)$$

$$= \frac{C^2}{a^2} \cdot \frac{dv \cdot dv'}{r^2} \cdot f(a)$$

which, if the linear dimensions be increased n times, becomes

$$dF' = \frac{C^2}{a^2} \cdot \frac{n^3 dv \cdot n^3 dv'}{n^2 r^2} \cdot f(a)$$

$$= n^4 dF$$

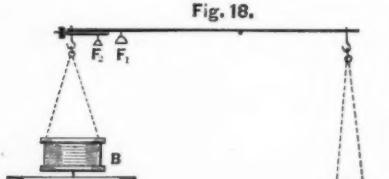
whence, since this is true for all elements of the circuits, $\frac{F'}{F} = n^4$, which is Deprez's so-called "law of similars," which asserts that for similar machines the "statical effort" increase as the fourth power of the linear dimensions. But work $W = F \times$ distance, and, in the similar machine whose dimensions are increased n times, the available distance through which the force F' can act also n times greater.

Hence $\frac{W'}{W} = n^5$, as above.

Suppose the machine to be "shunt" wound, then to produce the field of force of n^3 times as many square centimeters area, will require (if the electromotive force be n^2 times as great) that the absolute strength of the current remain the same as before in the field-magnet coils. This can be done by using the same sized wire as before, and increasing its length n^3 times, to allow for n times as many turns, of n times as great a diameter each, in the same number of layers of coils as before. In this case the work done in the shunt being equal to the product of the n^2-fold electromotive force into the unaltered current will be only n^2 times as great, while the whole work of the machine is augmented n^5 times. Now, if while augmenting the total work n^5 times, we have increased the waste work not to n^5 times but only n^2 times, it is clear that the ratio of waste to the total effect is diminished n^3-fold. There is therefore, every reason to construct large machines, from the advantage of economy, both in relative prime cost and relative efficiency.

Being desirous of testing the correctness of the deduction that the working capacity of a machine of n-fold linear dimensions is n^5 times as great, I constructed a little instrument, of which a drawing is given in Fig. 18. In this

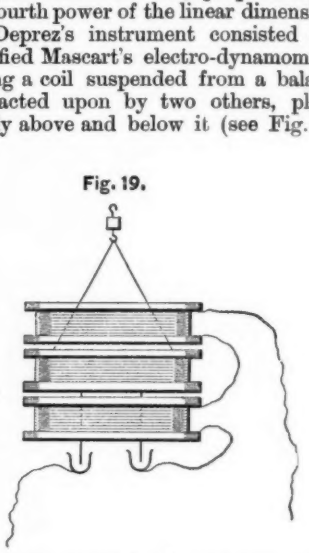
Fig. 18.



S. P. THOMPSON'S EXPERIMENTAL BALANCE.

instrument there are two pairs of coils, that on the left being, in every way, the counterpart of that on the right, but of double linear dimensions. When all four coils were traversed by the same current, the point of equilibrium was $\frac{1}{17}$ of the length of the beam from the extremity; or the attraction of the larger system was sixteen times that of the smaller. Now, it is clear that the larger force can be exerted through double the distance, or that the work-power is 32-fold, and 32 is 2^5, as theory requires. After I had constructed my apparatus, I learned that M. Marcel Deprez had made a very similar arrangement, but without the beam, to prove that the statical forces of similar machines are (see foot-note *ante*) proportional to the fourth power of the linear dimensions. M. Deprez's instrument consisted of a modified Mascart's electro-dynamometer, having a coil suspended from a balance, and acted upon by two others, placed axially above and below it (see Fig. 19).

Fig. 19.



MARCEL DEPREZ'S ELECTRO-DYNAMIC BALANCE.

The force was measured by directly balancing it against weights. Two such arrangements were made, one double the size of the other, and when equal currents were sent through them, M. Deprez found the forces to be as 5.600 to 0.355 kilos., or almost exactly 16 to 1.

Methods of Exciting the Field Magnetism.

It only remains to develop certain theoretical considerations respecting the method of exciting the magnetism of the field, in which the armatures are to revolve. The four main methods have already been alluded to at the outset of this lecture; but nothing has been said about the advantages or disadvantages of the four systems.

Magneto-Dynamos.—The magnet-dynamos (Fig. 4.) have the advantage in theory at least, that their electromotive force is very nearly exactly proportional to the velocity of rotation; though, of course, the variable difference of potential between the terminals of the circuit will depend on the relation of the resistance of the external circuit to the internal resistance of the armature coils. They possess the disadvantage that, since steel cannot be permanently magnetized to the same degree as that which soft iron can temporarily attain, they are not so powerful as other dynamos of equal size.

Separately-Excited Dynamos. — The separately excited dynamo (Fig. 3,) has the same advantage as the magneto-machine, in electromotive force being independent of its accidental changes of resistance in the working circuit, but is more powerful. It has, moreover, the further advantage that the strength of the field is under control. For by varying either the electromotive force or the resistance in the exciting circuit, the strength of the magnetic field is varied at will. It has the disadvantage of requiring a separate exciting machine.

Series Dynamos.—The ordinary, or series dymano (Fig. 1), is usually a cheaper machine, for equal power, than any of the other forms, as its coils are simpler to make than those of a shunt machine, and it wants no auxiliary exciter. It has the disadvantages of not starting action until a certain speed has been attained, or unless the resistance of the circuit is below a certain minimum. It is also liable to become reversed in polarity, a serious disadvantage when this machine is applied for electro-plating or for charging accumulators.

From its arrangements, it is clear that any increase of the resistance in the circuit lessens its power by diminishing the strength of its magnetic field. Hence it is better adapted for use with lamps arranged in parallel arc than for lamps arranged in series. An additional lamp switched in, in series, adds to the resistance of the circuit, and diminishes the power of the machine to supply current. While on the other hand, an additional lamp in parallel reduces the total resistance offered by the network of the circuit, and adds to the power of the machine to provide the needed current. It is easy to regulate the currents given by a series dynamo, by introducing a shunt of variable resistance across the field-magnet, thus altering the magnetizing influence of the current.

Shunt Dynamos.—The shunt dynamo (Fig. 2,) has several advantages over forms. It is less liable to reverse its polarity than the series dynamo, and it is commonly considered as providing the magnetizing power to the magnets with less waste of current. Moreover, for a set of lamps in series, its power to supply the needful current increases with the demands of the circuit, since any added resistance sends additional current round the shunt in which the field-magnets are placed, and so makes the magnetic field more intense. On the other hand, there is a greater sensitiveness to inequalities of driving in consequence of the great self-induction in the shunt. As previously pointed out, when there are sudden changes in the electromotive force acting in a complex circuit, the momentary currents thus set up do not distribute themselves in the various parts of the circuit in the simple inverse ratio of the resistances, for their distribution depends also, and in some cases chiefly, upon the self-induction in the various parts. It is more difficult to set up a sudden current in a circuit whose self-induction is great (or which, for example, consists of many turns wound closely together, so that they exercise great inductive action on each other, especially if they be wound about an iron core) than in one in which the self-induction is small. We cannot here follow further the mathematical law of the action of self-induction on momentary changes of electromotive force. But the application to the shunt-wound dynamo is too important to be passed over.

Any of these systems may be applied either in direct current or in alternate-current machines. Each of these four systems of exciting the field magnetism has its own merits for special cases, but none of them is perfect. Not one of these methods will insure that, with a uniform speed of driving, either the electromotive force or the current shall be constant, however the resistances of the circuit are altered.

But, though theory tells us that none of these systems is perfect, theory does not

leave us without a guide. Thanks to the genius of M. Marcel Deprez, we have been taught how to combine these methods so as to secure in practice a machine which shall, when driven at a constant speed, give either a constant electromotive force or a constant resistance. A consideration of the various methods of combining the four systems of exciting the field-magnetism is reserved for the lecture on the dynamo in practice.

Meantime, it may safely be said that there is no such thing yet as a best dynamo. As with the different kinds of voltaic batteries, some of which are used for telegraph work, others for electric bells, and others for blasting, so is it also with dynamos. One form is best for one purpose and another for another. One gives steadier currents, another is less liable to heat, a third is more compact, a fourth is cheaper, a fifth is less likely to reverse its currents, a sixth gives a greater volume of current, while a seventh evokes a higher electromotive force. Indeed, in the present transitional state of our knowledge with respect to dynamo-electric machinery, it is safe to assert that, for a long time to come, there will be no finality attained to. As with the steam-engine, however, so with the dynamo-machine, there will probably be a constant and progressive evolution, finally settling down upon two or three typical forms, which will survive the innumerable comparatively crude machines which, as yet, have taken shape and come into active service.

ELECTRIC LIGHTING IN MILLS.

Abstract of a Report by C. J. H. WOODBURY, Inspector of the Boston Manufacturers' Mutual Fire Insurance Company.

From Transactions of the New England Cotton Manufacturers' Association.

Expense.

The cost of maintenance of a system of lighting bears little relation to its intrinsic worth. The item of cost of lighting is a small fraction of the whole operating expense; and what is desired is to light a mill so well that there will be no difference in the character of day and night work, either in quantity or quality. Any expenditure beyond that is unwarrantable.

The question of the cost of lighting by electricity is subject to many legitimate variations, of which the question of power is most variable. In a steam-mill, where the dynamo is driven by the same engine that runs the mill, it is generally charged with only its share of fuel; but not with any other expense of power, wherever it does not introduce any new expenditures in the way of plant, repairs, or labor in the engine-room.

In following this plan for the sake of uniformity, with other estimates of the cost of electric light, I do not wish to be considered as endorsing this method of estimating. There is no reason why the electric apparatus should be supplied with power free of cost for transmission, interest, and supervision, which does not apply with equal force to every other machine in a mill, exempting it from these necessary items of cost. This paper refers only to the use of the electric light in mills, and not for circuit lighting, where the prime cost is much greater than in mills.

Some mills have departments which are only run by daylight, where work is thrown off at sundown, and so compensates for the power required by the dynamo. For example, in one mill using electric lights, the power used in the nepping-room is slightly more than is required for the dynamo; so, when the machinery in that room is stopped, the dynamo can be started without bringing any extra load on the engine. Most factories being driven by water power, with supplementary steam power during low water in the summer months, the electric lights would be required during the shorter days of the year at a time when there is usually an abundance of water; and the extra power can be used by the dynamo by the use of more water, without requiring any additional expense.

It is difficult to make a just comparison between various methods of illumi-

nation, because a change of light is always made an excuse for more light.

The majority of mills are lighted with gas made by the destructive distillation of petroleum, and of about eighty-candle power, which is generally reduced to sixty-candle power by mixing air with it, and burned through one-foot (nominal) burners, which consume about one and a quarter feet per hour, at the pressure generally used.

The annual cost of oil-gas per burner is from seventy-five cents to one dollar. In all these estimates, interest at six per cent. forms one item in cost. One large corporation, with exceptional privileges, makes its coal-gas at an annual cost of sixty-nine cents per burner. Another corporation, inland, makes its coal-gas at $1.25 per thousand cubic feet, at an annual cost of $1.79 per burner, each burner consuming 1,433 cubic feet annually.

Of two large mills in the same city, manufacturing similar goods, the more modern one makes oil-gas at an annual cost of seventy-nine cents per burner, while the older one buys coal-gas at $2.65 per burner.

Sometimes, when the gas-making apparatus is not managed with skill, the goods are damaged from soot which settles on them.

The following shows the cost of lighting a woolen mill with high-test kerosene oil, including wicks, chimneys, and matches:

Year	Lamps used.	Consumption of oil.		Cost.	
		Gallons Total.	Gallons per lamp	Total.	Per lamp.
1877.	125	167	1.33	$49.39	$0.40
1878.	140	387	2 75	84.63	.61
1879.	140	437	3.12	75.12	.54
1880.	140	408	2.94	89.34	.64
1881.	190	473	2.50	99.19	·52

The longer time light is required, the less the average cost, because, with the addition of operating expenses, the interest on plant, being a fixed amount, becomes a smaller proportion of the whole cost. In electric lighting, the cost of plant is so much that interest is an important item; and when a mill is run nights the relative cost of electric lighting is materially diminished. A white cotton mill, running sixty hours a week, generally uses light three hundred to three hundred and fifty hours a year; where they run sixty-six hours a week, lights are required four hundred to four hundred and fifty hours a year.

A dark mill requires about twice the number of lights that is sufficient in a white mill, and uses light about a hundred hours a year more than a white mill.

An arc light, as generally used in mills, requires about one-horse power. Mr. James Renfrew, Jr., at Adams, Mass., has found, by test, that the forty-light Brush dynamos in his mills each require 36.6-horse power. The lights were running in a satisfactory manner, but no photometric tests were made.

The cost of arc lights in several steam-mills, running four hundred hours per year, is 6½ cents per hour; of which one cent and a half is for carbons, and five cents for attendance, coal, depreciation, and interest. When a mill runs nights, the hourly cost is diminished.

The ratio of substituting electric lights for gas is quite variable, being one arc light to from ten to twenty gas-burners. In one mill lighted by kerosene the ratio was one arc lamp to eight kerosene lamps.

In a colored mill one arc light will light the looms on seven hundred to fourteen hundred square feet of floor; but in a white mill the same light will be sufficient for looms on a thousand to two thousand square feetof floor.

The reflected light from white walls and ceilings adds very materially to the diffusion. A card-room forty-eight by a hundred feet, containing sixty-four cards, was satisfactorily lighted by one arc light. The end of the room was extended about forty feet; and the light was not satisfactory toward that end of the room, where the light was formerly ample, because the removal of the end wall took away what served as a reflector.

It is advisable to place the conducting wires of lighting systems so that the different circuits will light similarly shadowed portions of the mill; one circuit reaching the darker places, another lighter parts, so that each of the various dynamo-machines can be used at their full capacity, as the total light in the mill is being increased or diminished.

It is convenient to compare the cost

of electric lighting with the expense of gas in the same place; although it must be remembered that gas does not furnish as much or as good light, and is therefore not so valuable where quantity or quality of light is of importance.

In a weave-room, on very fine work, twenty-four arc lights replaced 292 six-foot burners, which consume (292×6) 1,752 feet per hour, so one arc light represents the consumption of ($1{,}752 \div 24$) seventy-three feet of gas per hour. A careful estimate shows these arc lights to be costing $6\frac{1}{2}$ cents an hour; so this arc lighting system represents gas at eighty-nine cents per thousand. A similar estimate in another mill gives the annual cost of gas $2,188, and electricity at $1,125, or equal to gas at ninety cents a thousand. The annual saving to that mill in lighting expenses by the use of electricity makes a profit of $1,063, which represents six per cent. on $17,716, without making mention of any improvement in work or production due to that light. In both of these establishments the lights were used about 450 hours per year. Other estimates give the cost of arc lighting equal to gas at from sixty-five cents upward per thousand. In the case of incandescent lighting, the cost is more difficult to estimate, because they are run at all degrees of brilliancy, affecting both the power and the life of the lamp.

The duration of the carbon filament is the uncertain factor in estimating the cost of incandescent lighting. I do not know of any instance where all the incandescent lamps have become worn out by the ordinary use to which they are subjected, so as to reach an average of their ultimate duration.

The application of incandescent lighting is new, and the minimum guaranty of both companies may be considered as representing two years' ordinary use in a mill; and my experience in the matter has shown that this is largely exceeded.

The following records give the data of the longest time that I have at hand of the use of incandescent lamps; yet they are far from satisfactory, because they do not represent the average life of the carbons; because they are not all broken, no true average can yet be given.

Both the Edison and the Maxim lamps are guaranteed to average six hundred hours; yet in the New York Post-office the average record of the Maxim lamps is stated to be 2,200 hours up to Nov. 28, and four lamps had already burned 4,820 hours.

The ferry-boat "Jersey City," belonging to the Pennsylvania Railroad, is lighted by the Maxim lights. I have a copy of the official record of these lamps, dated Aug. 29, 1882, showing that at that time the average was 1,609 hours.

The data for the above were taken with lamps in use, and do not represent their ultimate endurance.

Mr. Timothy Merrick, of Holyoke, authorizes me to give the facts respecting his experience with the Edison system in the Merrick Thread Company's mill, No. 3. This mill runs all night, five nights in the week, for fifty-one weeks per year, using light 2,869 hours per annum. It was lighted by ninety-five burners with city gas, costing $2.13 net, which amounted to $225 per month. Ninety-five Edison B lamps (eight-candle power) were substituted for the gas. In the first thousand hours five lamp carbons had broken; and Oct. 20 they had been in use 1,278 hours, and eleven had broken.

Allowing that the lamps average six months' use, the annual cost of lighting is made up as follows:

Two renewals of 95 lamps equals 190 lamps at $1.00	$190 00
Interest and depreciation	153 50
Six-horse power at $10	60 00
Annual cost Edison light	$403 50
Monthly cost Edison light	33 62
Monthly cost gas	225 00

The results from these lamps are very satisfactory, and certainly in excess of what would have been obtained if the lamps had been forced beyond their normal capacity.

The Holyoke Water Power Company furnish water power very cheaply; and the result may be interesting if we hold the Edison Company to their minimum guaranty, and also charge the dynamo with four pounds of coal per hourly horse power.

$4\frac{78}{100}$ renewals of 95 lamps equals 454 lamps at $1.00	$454 00
Interest and depreciation	153 50
$30\frac{74}{100}$ tons coal at $5.75	176 81
Annual cost Edison light	$784 31
Monthly cost Edison light	65 36

which is equal to gas at sixty-five cents per thousand.

The mill is situated at the base of a high bank, and is only eleven feet six inches between floors, so it is very hot in summer; and Mr. Merrick informed me that it would have been impossible to run the mill nights during the extremely hot season last summer, if the help had been subjected to the heat and vitiated air from the burning gas.

It must be kept in mind that an instance of a mill running day and night is an extreme one in favor of the electric lights; but the data are given, and the matter can be estimated to suit other times of operation.

If these electric plants were charged the proportionate cost of power, besides coal, the cost would be estimated greater than stated above.

Experience with Electric Light in Mills.

The general opinion of a great number using electric light in a practical way is of more weight than the conclusions of any single investigator.

In the pursuance of my occupation as inspector, it has been my duty to examine nearly every textile mill and many other establishments in New England, New York, New Jersey, and Pennsylvania, where electric lights are used.

I do not recall a single instance where the *quality* of the light was unsatisfactory.

A few extracts from my correspondence on the subject will show how it is regarded by those who deal with electric light solely in regard to its merits in practical application.

As none of these letters were written for publication, I do not feel authorized to give the names of the various writers; but all are either the executive or financial heads of mills insured in the mutual companies. It is but a matter of justice to the confidential nature of my occupation as an inspector, that this anonymous use of letters has been agreed to by their writers.

The letters from woolen mills will first be read. The proprietor of a fourteen-set woolen mill writes:

> We have had forty-four Fuller arc lights in operation six months without any repairs. In the weave-room two hundred and eighty kerosene lamps were replaced by eighteen electric lights.
>
> Electric light costs more than kerosene; but I am quite willing to stand the extra expense, as there is as much improvement in the light as the extra expense would represent. The air is not contaminated, and no overheated rooms, as is the case when using so many kerosene lamps. The help all like them, and their work is more perfect. Our warps are all black; therefore, more light is needed than on light work.

The treasurer of another woolen mill using the Brush arc light writes:

> On account of the flood of light furnished the weavers, thus enabling them to make perfect work, as well as on account of the purity of the atmosphere, we feel that the production is increased to such an extent that we think that we cannot afford to do without it.

The superintendent of a woolen mill manufacturing dark goods, where the Edison incandescent light is used, writes:

> We find the running cost of the Edison light to be one-fourth that of gasolene vapor, formerly used in our mill. Regarding the advantages of the light, it is better, safer, and cheaper, and devoid of smell or heat.

The president of a woolen mill, a portion of which is lighted with Weston arc lights, writes:

> The dyamo-machines were put in ten months ago, and have not yet cost us anything for repairs. We cannot well estimate the actual cost of the light. We have an abundance of power. The cost of carbons thus far has been $3.52 per lamp for ten months.
>
> It is used in finishing, burling, and repair departments, and is well adapted for our carding and spinning rooms.
>
> So far as we have had experience with them, we approve of the light.

The manager of a woolen mill formerly lighted by petroleum gas, which has been replaced by Brush arc lights, states:

> Cost is greater, of course; but we like the light, and don't mind the expense.

It should be added in this connection that these Brush lights furnish much more light than would be possible to obtain from oil-gas.

The superintendent of a woolen mill,

where the Edison incandescent light is in use, writes:

The light is certainly superior to gas-light, and is much liked by the workmen, particularly the dressers, who require a very good light; and where warps are dressed in different colors it is highly satisfactory in distinguishing the same, which is difficult and sometimes impossible to do by gas-light.

From a few mills on colored cotton goods I select the following. In one mill where the Weston arc light is used, the agent expresses his opinion that—

The excellence of this electric light consists in its brilliancy, steadiness, and freedom from tendency to vitiate the air. For our particular purpose it also has the advantage of being unaffected by the current of air from the dresser fans.

From a gingham mill lighted by Brush and by Weston arc lights we obtain the following information:

We have a thousand looms lighted with fifty lamps, giving ample light, more than we obtained with a gas-jet at each loom. I believe that we could light more than twenty looms to a light; but with these we get a splendid light, which is the same to us as gas at sixty-five cents per thousand feet. We would not change back to gas

The manager of a print-works using the Weston arc light states:

We have experienced no trouble whatever, and can only speak of the light in its most favorable terms.

The agent of a fine cotton mill lighted by the Brush arc light, gives this opinion:

Our experience leads us to the belief that a system of electricity is to be the artificial light of the future, especially in buildings of any magnitude.

The superintendent of a cotton mill lighted partially by the Maxim incandescent, and partially by the Weston arc lights, sums the result of three years' experience:

We have always considered it a success as compared with gas, as being a better and more economical light.

The experience of the manager of a silk mill with the Thomson-Houston arc light leads him to state:

We have twenty arc lights over seventy-five looms on silk and tapestry weaving. We consider the light far superior for our purpose to anything that we have ever used. It is especially useful in distinguishing colors. The power necessary to run the machines has, we think, been under-estimated, taking a full horse power to each light. The cost of maintaining the light has been very small; the item of repairs not yet coming in, as none have been necessary. We have an abundance of water power.

The following information is furnished by the officers of two cordage mills, one states:

We run four Weston machines of ten arc lights each, making forty lights in all. It requires $32\frac{5}{10}$-horse power to run the whole. The cost of running is about $1.75 per hour; this includes expense of carbons, man's time attending and trimming the lamps, wear and tear, and interest on original plant.

The lights have been used from one to four hours daily for five months in each of the past two years, without repairs; and we are so well pleased with their working that we are putting them up in our new mill.

Although these lights are reported as perfectly satisfactory, they could not have been regulated to the standard brilliancy. On long circuits, arc lights require about one and a quarter to one and a half horse power each; the power being measured at the cylinder of the engine.

The superintendent of a similar mill, where the Arnoux & Hochhausen arc light has been used for some time states:

We have expended nothing upon them for repairs, with the exception of brushes and other minor articles. I consider the electric light to be far superior to any that I have ever used, in point of brilliancy and steadiness.

The list might be continued to greater length; but enough has been given to show the favorable nature of the experience of the industries represented in this association, with the practical application of the various types of electric lighting apparatus in general use.

Of the arc and incandescent lights, both have zealous advocates. While each has merits which fit it for special work, there is a broad middle ground where both are used with success; and the decision as to their relative merits is indeed a difficult task, and the final result must often be one of personal judgment.

Electric arc lights are used in various large buildings, as foundries, rolling-mills, forges, boiler-shops, and dye-houses, with great success.

In no other place does the arc light show such a marked superiority over

other methods of illumination as in these industries. In one instance incandescent lights were unsatisfactory in the erecting department of a large locomotive shop, while arc lights have been used with success in similar places.

The incandescent light is the better adapted for places where the light must be localized, and would be obstructed by objects which would throw shadows if the light came from some remote source, as in the case of an arc light.

A weave-room two hundred and thirty-five by fifty feet, and ten feet high, contained two hundred and twenty-four yard-wide cotton-flannel looms, which were lighted by a hundred and fifteen gas-burners.

Thirteen Brush arc lights were placed in this room, the light being seven feet from the floor, requiring one light to seventeen looms. Twelve of these identical lamps were removed to another mill in the same yard, and one hung in the engine-room; but the dynamo was not moved, nor its speed changed.

The new weave-room measured two hundred and nineteen by ninety-five feet, and was fifteen feet in height; the light being twelve feet from the floor. Owing to the greater height of the room, these arc lights illuminated three hundred and eighty-four looms, or thirty-two looms to a lamp, in place of seventeen in the former mill.

In the first instance there were nine hundred and four square feet of floor to a light, and in the second seventeen hundred and thirty-four square feet of floor to a light.

This is given as an instance showing how much surrounding conditions have to do in each case. In the first mill incandescent lights would have been cheaper, and in the second this would have been reversed.

Other instances need not be cited, as it is not our object to deal with applications of electric light other than for mills.

Safeguards of Electric Lighting.

The experience of the insurance companies in regard to electric lighting has constituted the subject a factor in underwriting. It is difficult to estimate the amount of hazard to which property is subjected by its use, because the elements of danger are diminished by suitable precautions. The hazards attending the use of the electric light have been overestimated; not in numbers or magnitude, but because too little account has been given to the preventable nature of such occurrences. If these precautions are disregarded, only good luck will avert disaster.

It is sometimes assumed by those ignorant of the facts, that electric lighting apparatus cannot set a fire. Electricity is no exception to other forms of energy. All power can be converted into heat. Your mills are equally liable to hot bearings, whether the motive power is derived from the fires under the boilers, or to the head of water in the mill-pond.

Whenever any one states, as a principle, that the electricity used for lighting cannot set fire to anything, he is not only in error, but is uttering a fallacy which will lead to the destruction of property, if carried into effect in any electric lighting system.

It is better to meet the issue fairly, and the interests of all will be advanced by the consideration of its dangers; for in no other manner can suitable measures for protection be reached.

In the Mill Mutual Insurance Companies there were sixty-one establishments lighted by electricity up to last May.

With few exceptions, the lights had not been in use previous to the autumn of 1881; and many had been started early in the spring.

In these sixty-one establishments I know of twenty-two fires due to electric lighting and assignable to the following causes: Eight were from globules of melted copper or particles of hot carbon falling out from the bottom of the globes. The actual number of fires from this cause was probably many times this number. That class of fires will not continue to happen, as all makers now set their lamp-globes in a tight stand with a ridge around the edge. A flat plate will not answer the purpose, as there was one instance where drops of melted copper rolled off, and set a fire.

Four fires were due to leaking water or washing floors; and two more were caused by water in a dye-house, condensing on the building to which uninsulated

wires were fastened. In most of these instances a grounded circuit formed one of the two connections necessary to divert the electricity from the wires. Many of the lower carbons fell from lamps, and five fires were caused where they fell upon combustible material.

Three fires were caused by cross arcs from one wire to another, where uninsulated wires were fastened against conductors. In one instance the conductor was formed by dust settling upon uninsulated wires; and on a damp day it absorbed enough moisture to form a path for the formation of a cross arc, which started a slight fire.

In another instance the wires were fastened to a damp beam, which was decayed, and was burned nearly in two by the smouldering fire. And in the third instance damp brickwork in a tunnel was a sufficient conductor to establish an arc which did not do any material damage there, but injured the dynamo. Reference has been made to other fires produced by cross arcs started by water, forming a connection between two wires.

In my connection with electric lighting matters for the Boston Fire Underwriters' Union, I know of two fires caused by improper switches; two by water reaching the wires of a circuit already grounded; and one from wires coming in contact with a building, so that their insulation was worn away. There have been many fires from electric apparatus in districts outside of those where I have business, and I do not feel called upon to make any reference to those instances in this connection.

No reference is made to accidents which did not set any fires, although fires would have ensued from many accidents if combustible matter had been present.

I believe that all these fires should be classed as avoidable fires, because the use of well-known precautions would have anticipated their possibility.

The precautions are known only as a matter of experience, because there was no source of information stating the results from electric lighting currents under certain circumstances.

The damage from these fires was in each instance small, as would be expected. It is the experience of the Boston Manufacturers' Mutual Fire Insurance Company, that in mills three-fourths of the fires are in the daytime, and three-fourths of the losses are in the night; so the chance of loss in the night is nine times as great as in the day. During the last two years the introduction of automatic sprinklers has reduced the damage from night fires one-half.

As the electric lights are used during working hours, these accidents come under the head of day fires. When they have happened, there has always been a sufficient number of employes engaged on the premsises to attend to the matter at once. When electricity is diverted from the system, the lights are correspondingly diminished, and general attention directed to the difficulty.

Eyre M. Shaw, Captain of the Metropolitan Fire Brigade of London, when in Boston, during his recent visit to America, stated to me, that, since the introduction of the electric light, there had been about one hundred fires in London from this cause.

Electricity forms the safest method of illumination when the following precautions are observed: The system insulated throughout, so that there is no electricial communication with the earth, or from one part of the apparatus to another, except through the proper conductors, even if the wires should be exposed to water. All switches made with a lapping connection, so that no arc can be formed. Arc lamps provided with globes closed underneath, and the frame so arranged that the lower carbon could not fall out even if the clamp failed to hold it securely.

The wires of incandescent systems provided with a sufficient number of fusible links to secure the system against any damage from an excess of current.

The carrying out of these principles in every detail requires careful work and constant watchfulness.

Other features in an electric lighting system are advisable to assure the most satisfactory operation of the apparatus and protection to persons, but they may not be essential to secure safety against fire.

The insulation of a system can be assured only by frequent tests. The best

instrument for ordinary use is a magneto which generates an alternating current, and rings a bell like the ordinary telephone "calls." It is used by connecting one wire to the ground and the other to the system. The presence of a fault is indicated by the ringing of the bell when the magneto is put in operation. Means for the systematic trial of the insulation are relatively as important as the use of gauge cocks on boilers.

If an electric lighting system is sufficiently insulated when first arranged, there is no assurance that it will remain so, on account of the numerous changes, blunders, and accidents to which it is subjected. Unfortunately we are not forewarned of any lurking disarrangement of electric apparatus by means of any of the senses, in the same manner that leaking gas appeals to the sense of smell, or as leaking steam produces sound and vapor.

When electric lights become dim in rainy weather, it is conclusive evidence of ground connections, which divert the electricity from the system, causing both commercial loss of electricity and great danger of fire. Two contacts are necessary to divert electricity from an electric lighting system. If one contact already exists, and connects it with the earth, only one more contact is necessary to conduct a portion of the electricity from the system.

In such an event, if the electricity overcomes a conductor of sufficiently high resistance, the electricity is converted into heat sufficient to burn any combustible substance which is present.

Underwriters have two methods of defence against a special hazard—the one to advance the rate to an amount deemed commensurate with the increased danger; and the other method consists in the removal of the source of danger.

With electric lighting, the hazard, not an inseparable part of the system, can be obviated by the measures which have been referred to, and which are applicable to all systems of electric lighting.

In preparing the regulations for the Fire Underwriters' Union, I did not ask for any precaution not found by the experience of accidents and actual fires to be essential to protect either person or property.*

* Regulations of the Boston Fire Underwriters Union for the Use of Electric Lighting Apparatus.

Wires.—Conducting wires over buildings must be seven feet above roofs, and also high enough to avoid ladders of the fire department.

Whenever the electric light wires are in proximity to other wires, dead guard wires must be placed so as to prevent any possibility of contact in case of accident to the wires or their supports. Conducting wires must be secured to insulated fastenings, and covered with an insulation which is water-proof on the outside, and not easily worn by abrasion. Whenever wires pass through walls, roofs, floors, or partitions, or there is liability to abrasion, or exposure to rats and mice, the insulation must be protected with lead, rubber, stoneware, or some other satisfactory material. Wires entering buildings must be wrapped so that water cannot enter through the tubes.

For inside use loops of wire must be avoided, and the insulated fastenings arranged to keep the wires free from contact with the building.

Joints in wires to be securely made and wrapped. Soldered joints are desirable, but not essential. Wires conducting electricity for arc lights must not approach each other nearer than one foot; and for incandescent lamps the main wires must not be less than two and half inches apart.

Care must be taken that the wires are not placed one above another, in such a manner that water could make a cross connection.

A cut-out which can be operated by the firemen or police must be placed in the circuit in a well-protected and accessible place.

Lamps.—For arc lamps the frames and other exposed parts of the lamps must be insulated from the circuit. Each lamp must be provided with a separate hand switch, and also with an automatic switch which will close the circuit, and put out the light whenever the carbons do not approach each other, or the resistance of the lamp becomes excessive from any cause. The lamps must be provided with some arrangement or device to prevent the lower carbons from falling out, in case the clamp should not hold them securely.

For inside use the light must be surrounded by a globe, which must rest in a tight stand, so that no particles of melted copper or heated carbon can escape; and, when near combustible material, this globe must be protected by a wire netting. Broken or cracked globes must be replaced immediately. Unless a very high globe is used, which closes in as far as possible at the top, it must be covered by some protector reaching to a safe distance above the light.

For incandescent lamps the conducting wires leading to each building and to each important branch circuit must be provided with an automatic switch or cut-off, or its equivalent, capable of protecting the system from any injury due to an excessive current of electricity.

The small wires leading to each lamp from the main wires must be very thoroughly insulated, and, if separated or broken, no attempt made to join them while the current is in the main wires.

Dynamo-Machines.—Dynamo-machines must be located in dry places, not exposed to flyings or easily combustible material, and insulated upon wood foundations. They must be provided with devices capable of controlling any changes in the quantity of the current; and, if these governors are not automatic, a competent person must be in attendance near the machine whenever it is in operation.

Each machine must be used with complete wire circuit; and connection of wires with pipes, or the use of ground circuits in any other method, is absolutely prohibited.

The whole system must be kept insulated, and tested every day for ground connections, at ample time before lighting to remedy faults of insulation if they are discovered.

Preference is given for switches constructed with a lapping connection, so that no electric arc can be formed at the switch when it is changed; otherwise the stands of switches, where powerful currents are used, must be made of stoneware, glass, slate, or some incombustible substance which will withstand the heat of the arc when the switch is changed.

The effects of an electric lighting current upon the person bear no relation to the injury which that current can do to property. Electricity has the two properties of quantity and tension, which are independent of each other. The heating effects are due to the quantity, and the results upon the person are proportional to the tension, of the electricity.

However, the greater the tension, the more liable is the electricity to force its way through bad conductors. The arc light is produced by a current of high tension and small quantity; the incandescent light is formed by a current of low tension and great quantity.

Therefore, in the arc light system the most secure insulation is essential; but with incandescent lights, if the insulation were ineffective, there would be more liability of fire. In incandescent lighting systems the whole reliance for safety is not placed upon the insulation; but small fusible links are placed at various points in the wires, so that, if the quantity of the current exceeds a certain amount, the fusible link will be melted, and cut off the electricity before other damage could ensue.

Although these safety catches were originally devised for the purpose of protecting the carbon filaments of incandescent lamps from destruction by extra currents, yet they are essential to assure safety against fire; and it is the use of these safety catches, and not from the fact that the electricial portions of the system can be handled with impunity, that has given the insurance interest somewhat of a bias in favor of incandescent lighting.

Electric lighting should be encouraged on account of its inherent qualities of safefy. Any system that is in conformity to the insurance regulations is also in its best condition electrically.

Electricity, like all forms of energy, is dangerous to the extent that it is not held in control. The same is true of steam in boilers, or water in mill-ponds. Like fire, they are all "good servants, but poor masters."

Discussion.

Mr. Edward Kilburn.—I think, after the exhaustive remarks of Mr. Woodbury, it would be folly for me to attempt to say any thing more than to state that we have just adopted the Edison incandescent system of lighting in our No. 6 mill, Wamsutta Mill, New Bedford, and we have three of the Edison K dynamos, equal to 360 A lights each of sixteen-candle power; and we are running in the mill regularly seven hundred and twenty lights. On Saturday last we weighed the power required to produce these lights, and we found it to be 63.7 horse power, or 8.6 lights to a horse power; and we light four looms to a light, and so proportionately throughout the mill. The mill has some 51,000 spindles in it; and (we have not had it long enough to determine very definitely about it, but so far as we can see now) we believe it to be as cheap as gas at fifty cents a thousand. We are unable to see it in any other way. I don't know that I have any thing more to say on the subject. Mr. Woodbury has said all that is necessary on the other part, much better than I could. The lights prove with us very satisfactory. It is certainly a beautiful light, and it is free from heat and smoke, etc. Our help like the lights very much indeed, and are very anxious to get from the other mills into this mill, and assign as a reason the electric lights. And we have help come from other mills; and we are overrun with help to-day, and a great many assign as a reason for their coming the electric lights. We run the lights from the engine which drives the mill.

Mr. C. W. Lippitt.—I certainly agree with Mr. Kilburn, and commend to the fullest extent the excellent address on electric lighting, which I have had the pleasure of listening to from Mr. Woodbury. I feel there is very little now for me to say. There is one point I would like to refer to before giving some figures, however, which I hope will not be without interest. That is, when I received the notice to appear here to-day in connection with electric lighting, I felt compelled to notify the Secretary, as I admit, that it would be impossible for me to consider the scientific part of this system. My connection with the electric light has been for a year or two enly, and that entirely of a commercial or manufacturing nature. The particular matter concerning which I suppose you will expect to hear from me to-day consists of a portion of the experience of the Social Manufacturing Com-

pany with electric lighting in the Globe Mill, belonging to that corporation, at Woonsocket, R. I. In the fall of 1879, I think, a twenty arc light Brush machine was purchased and put in operation in the mill. It answered the purpose very well, cutting out a large number of lights, and giving satisfaction for a year or two. Since then that machine has been changed; and we are now using two ten-light Weston arc machines, They also have given us good satisfaction. Our experience with the arc light was of such a character that it tended to increase the inclination, felt by several members of the corporation, to try in a cotton manufacturing establishment an incandescent light. Several attempts were made to get a plant of this character; but we were obliged to wait some little time before we could get one which promised to be satisfactory. The machines which we are now using were furnished by the United States Electric Lighting Company of New York. At the time that I applied to them for this plant, about a year ago, they were just on the point of bringing out their present system of electric lighting, and were very much averse to letting me have the machines that we are now using. The reason was that the present system that they are now introducing is far superior to the old system which we have now in use. It was only after a good deal of urging that I obtained permission to put the machines in. It was with the distinct understanding, that, in case at any time any of the results that were obtained from our present plant should be used or published in any way, a careful statement should be made calling attention to the fact that they were old machines, and that they did not produce as good results as can be produced by the new machines. For instance, the most important point perhaps in connection with these machines that we are now using, in which they are inferior to those that are at present being sold, is that it requires one-horse power to produce between three and four lights; whereas the machines that are now being sold will produce from seven to eight lights to a horse power. We have two dynamos, and in connection with them there is a regulator which it is necessary to use with these old machines. The plant, including the cost of the dynamos and the regulators, the foundation, belting, the shafting, the labor necessary to put it up, and everything complete ready to run, cost $2,552.90. An important part of the expense of running electric lighting is in the horse power. That I have tried to get at as carefully as possible. The power is taken from the main engine of the mill, that runs about fifty revolutions a minute. It is a double Corliss engine. The expense of the horse power—including interest on the cost of the engine, foundations, the building, the boilers, and so on, taking forty-five thousand dollars to cover those items, also including the coal, the labor, and every other expense that could be fairly charged against the power, whether used for electric lighting or for the production of yarn in the mill—figures down to $\frac{9.2}{100}$ of a cent per horse power per hour. That is a little over thirty dollars per horse power per year. As this was so near to one per cent. per horse power, and as that is the ordinary price, I believe, for calculating the power for electric lighting, I have taken in these calculations one cent per horse power per hour as the cost of the power. Following, then, the calculation, I find that eight per cent. interest on the electric plant gives me $204.23. It was also found, by carefully testing the engines when they were running the electric lighting machines and nothing else, that they were developing for these two incandescent machines thirty-horse power. Thirty-horse power, at one cent per horse power per hour, figures thirty cents per hour for the horse power. The lights ran during the winter of 1881 and 1882 three hundred and sixty-seven hours. That would give us $110.10 for the cost of the power. The breakage is the next important item. The lights are now guaranteed to burn six hundred hours. Although the lights only ran three hundred and sixty-seven hours, I have taken the actual breakage. Of course that breakage would cost us nothing, but still I have figured it in. The actual breakage of these lights for three hundred and sixty-seven hours was twenty-seven. They were renewed at an expense of fifty cents each, which gives us $13.50 for the breakage. The dynamos and the regulators were taken care of by the engineer who had charge of the main engine, with-

out any extra expense, and consequently nothing is to be charged to the cost of the light for that care. The amount of repairs was practically nothing. After the lights had been running for a few days, some difficulty was found in managing them, and a man came on from New York to remedy the trouble. There was a small bill for his time; but that of course was no part of the repairs, and I have not included it. It was about twenty dollars. The total cost of burning one hundred and seventeen incandescent lights for three hundred and sixty-seven hours was $327.83. We burn one light to four looms. That enabled us to cut out two hundred and twenty gas-lights that were called four feet burners each. Two hundred and twenty gas lights burning four feet per hour, with gas at $2.20, burning three hundred and sixty-seven hours, cost us $710.60. In estimating the actual cost of the gas, it is necessary to include interest on the piping that is used to carry the gas about the mill, in the same way as we have considered interest on the wires and the dynamos that carry the electricity about the mill. I have allowed six hundred dollars for the cost of the piping, which would be on the basis of thirty-five hundred dollars to pipe the mill carrying twelve hundred ordinary gas-lights, which I understand is a fair estimate for that expense. Eight per cent. on this sum gives us forty-eight dollars; making the total cost of the gas that would have been used in place of the electric light $758.60. That makes a saving in the use of the electric light of $430.77, or a percentage of fifty-seven per cent. The result with these old style electric machines, producing only three and a quarter incandescent lights per each horse power, burning them for less than four hundred hours, was an actual saving on the cost of gas of fifty-seven per cent. in favor of the electric light.

At one of our other mills we have been using an oil gas. That of course, as cotton manufacturers understand, is considerably cheaper than coal gas. I have made some figures in connection with this oil-gas, which, as near as I can ascertain, are accurate. The cost of the oil gas plant, for a mill using from eleven to twelve hundred burners, is $8,423.29. Estimating the cost of the piping for such a mill at $3,500, it gives us $11,923.29 as the cost of the plant for oil gas. Interest upon this sum at eight per cent. is $953.86. The cost of the oil labor, running expenses, and everything connected with the production of the gas for a winter, taking a year in which the cost of oil was, as I understand, just about what it is to-day, from eight to eight and one-half cents, the total of all these expenses, including the oil, was $941.01; making a total cost for the oil gas that season of $1,894.87. The cubic feet of gas produced by this expenditure was 483,900 feet, making a cost per thousand of $3.91. The burners in the mill where this gas is used for illumination are called one and a half foot burners. If we burn less than that, the figuring would be a little different; but that is practically correct. The cost of two hundred and twenty burners burning one and a half feet of oil-gas per hour, and running for three hundred and sixty-seven hours, is $473.11, against $327.83, the cost of the electric light. The number of burners used with the oil-gas was one burner to two looms. The number of incandescent electric lights was one to four looms; making a saving in favor of the electric light of $145.28, or a percentage of saving over the oil-gas in favor of the electric light of thirty-one per cent. I consider the electric light superior to any other form of illumination, for several reasons. First, on account of the absence of heat. Second, it gives more light for the same money than any other system of lighting. Third, it is fully as safe, if not safer, than any other method of illumination. A very large fire at one of our mills, which caused us a loss of over a hundred thousand dollars, was occasioned by the burning off of a gas-pipe. While there are some dangers connected with electric lighting, they are of a characte that can be better guarded against than the dangers connected with any other method of lighting. It is no more than fair to the United States Electric Lighting Company, who furnished these machines to us, that I should call the attention of the association particularly to the fact that these results, although they are sufficiently favorable to the electric light, have been produced by an apparatus that they were unwilling to dispose of on account of the defects that they knew were inherent in that system. Their present

system will produce lights giving twenty-four to twenty-five candle power each, and from seven to eight lights per horse power. These, as you have heard read at the desk, have lasted a very much longer time than six hundred or a thousand hours. As far as the result of our experience with the incandescent electric light is concerned, I can say that it has been so far satisfactory. As far as I know, it is regarded by almost every one connected with the mill as the most superior form of lighting that we have. As an indication of our appreciation of it, we are this year to increase our plant some two hundred per cent.; and the new mill that we are building will probably be lighted entirely by the incandescent system of electric lighting.

Mr. LIVERMORE.—Since your Secretary asked me to state the facts that have come to my knowledge in the use of electric light, I have endeavored to gather some statistics which we have collected in the use of the arc light in the Amoskeag Mills, which I will give you. We began using the Brush electric light in February, 1881, and have used it ever since. We are using four hundred and sixty-four arc lights, about half the Brush and half the Weston. We light about five thousand looms with them, besides some carding and spinning. I have fifteen rooms, large rooms, some of them having fifty thousand square feet, with these lights. They are hung, the lights are hung, all the way from eight feet and five inches to ten feet and five inches above the floor—usually above looms; and those heights, all of them, seem to give satisfactory results. I think in one case there is twelve feet and ten inches, and I think that that height is probably a little better than one lower. During the last eight months, since the position of the lights which we have had in use has been permanently settled, I have had an accurate account kept of the carbons used, and the number of hours that the lamps have burned, also the expenses for carbons, labor and repairs; and the use of carbons has been about thirty-seven thousand, about equally divided between the Weston and the Brush lamps, and they have burned to that extent that they have furnished one hundred and ninety-eight thousand lamps for one hour. In other words, the number of hours multiplied by the number of lamps gives one hundred and ninety-eight thousand of what we call units of the electric light for the purposes of our statistics. The total cost for carbons, labor, and repairs—and in repairs we include brushes and all those things that are worn out—has been five thousand seven hundred dollars. That has made an average expense of 2.89 cents per hour for each light. Now, that expense is subject to variation, because we have used some very poor carbons, and also because, I suppose, as the lamp-trimmers get more expert they will trim more lamps for the same wages. The carbons vary as much as oil in their quality. Good carbons ought to furnish light at the rate of one carbon for one lamp seven hours; but I have had them run down to four and one-half. The average of these carbons that I have made this calculation upon was, in the Weston lamp 5.14 hours, and the Brush 5.59 hours. Now, to the cost of 2.89 cents per hour per light is to be added the cost of power, the wear and depreciation and the interest. I do not think that it is safe to say that an electric light can be run without any cost for power excepting the extra coal used; because, while that may do on a small scale, yet I think, as a general rule, you cannot burn the candle at both ends without making it burn faster; and, for every hour that you use the electric light, I think you ought to charge for wages in making power, and for wear and depreciation. The same way I think you ought to charge for wear and depreciation of the electric plant. Supposing that you charge for power, every hour in Manchester, steam power, including interest, can be made for fifty dollars per horse power per annum. That may be thought large, but it is a safe estimate. That would make a horse power 16.7 cents per day. If you take out interest it reduces that considerably. Now, whether you run electric light one hour or two hours or six hours in a day, the interest on your plant is running for the whole day; so it is upon the steam plant that you put in to run that electric light; so that if you want to be safe you must charge the interest for the whole day against the electric light, whether you have run it one hour or more hours. Now, taking these figures that I have

given, and reckoning the depreciation and wear of the electric light plant on a cost of two hundred dollars a light—which is a liberal estimate at the present prices that the electric companies charge—charging interest at six per cent. both on that plant and the steam plant, and wear and depreciation at ten per cent., it will make the cost per hour for the arc light 4.8 cents without interest; with interest, for one hour it makes it 10 2 cents. Then for two hours it would be 15.2 cents; half of that for one hour; for three hours, 20.1 cents; four hours, 25 cents; five hours, 30 cents; making the cost diminish very rapidly as you increase in the use. I have compared that with the cost of gas at $1.60 a thousand, which is what we pay in Manchester: and the electric light, supposing that one arc will displace twelve gas-burners, for one hour would cost at that rate for gas, to displace gas, at the rate of $2.04 a thousand; for two hours, at the rate of $1.52 a thousand; for three hours, $1.33⅓; four hours, $1.25; five hours, $1.20 a thousand—unless I have made a mistake in the figuring; but I have given the items, upon which any one can figure for himself. We have colored work, and we have found that one arc light will take the place of twelve gas-burners over looms. We have had one gas-burner over a loom, and one arc light lights twelve looms well; possibly it would light more, but we prefer an abundance of light, because we think there is economy in it, and we have not yet found that we could light, on the average, over twelve looms with one arc light. I have heard it said here, and read in the letters, that an arc light will light, I think, twenty colored looms in some instances; but that is not our experience. If any one undertakes to introduce electric light in the place of gas that he has been using, and expects to realize in the cost of light itself the saving which these figures show, he will be mistaken, because the electric light will be used more than gas is. Our experience is, where a great deal of gas is used in a room, that people hold off as long as they can, because of the heat and of vitiating the air. They have no such scruples with the electric light. Unless people are more watchful than I have been able to be, they will find that the electric light is run more, and therefore the saving will not appear in the balance-sheet as to light, but I am confident it will appear in the quality of the work and in the quantity of the work. The difference between weaving in summer and winter, of course, is well known; and one of the results of the electric light, I think, will be to reduce that difference very considerably. I have heard it remarked, and have believed, that weaving-rooms which were dark, by reason of being basements, were now considered as good as those above ground, because of the electric light. I know that our weaving has improved both in quality and quantity, but I cannot attribute it all to the light; I do some; how much I cannot tell, because the causes have so commingled that we have not been able to get the result separate. As to the average number of hours which an electric light will be burned, I find, upon comparing the gas accounts in some fifteen carding and spinning rooms in our mills, that the average during the year for burning gas runs all the way from one hour to three hours; depending upon the situation of the rooms, whether they are dark or light rooms, and what their dimensions are. And I think it may fairly be calculated that any carding and spinning room well constructed and well lighted will during the year average to burn light in all its burners an hour and a half. Now, if power does not cost anything but for coal, and the electric light will displace twelve or more burners, then it is going to be a good deal cheaper than to use gas at the rate which we can get it. I have had the power required to drive the Weston machines tested by dynamometer. and it resulted in showing a little less than ten-horse power for ten lights; but I do not think it is safe to reckon less than ten horse power for ten lights. I have also compared the power required to run one hundred and twenty Weston lights with one hundred and twenty Brush lights upon forty-light machines, by noting the gate upon the water-wheel which drove them when the wheel drove nothing else, and noting the heights of the water, and there was not enough difference to be worth counting in computing the cost of electric lights; so that I think a horse power per light is what may be safely counted upon to drive

either the Brush or Weston arc lights. I have tried two other arc lights. but I don't know the power that they require. They were not satisfactory, and we have not continued the use of them.

Mr. LUDLAM—Mr. President and gentlemen, I have had some little experience with electric lights; but it is a subject altogether too new to arrive at any opinions with regard to results that we may look forward to as really fixed. I have in use at present some arc lamps of the Fuller system, and also some arc lamps of the Weston system. I am using them in part of my dye-house, where, owing to the conditions, the rooms are dark, and in some places artificial light of some sort is necessary all the time; and under such circumstances there is no question about the economy of electricity as compared with gas. The subject has been so completely ploughed and harrowed this morning that there remains very little more to say. The fundamental point seems to be, however, the question of interest as divided into the length of time during which the lamp is used; that is, when you come to consider the question of economy. In my place, apart from matters of economy, the light has another advantage with respect to the question of color. I have the light in use in two places where it is very important that we should be able to distinguish shades of color, and note any variations, and see that everything is kept to the shade we want; and there, of course, taking that advantage alone into account, the light is very valuable to us. With regard to the question of power, it seems to me that it is perfectly fair to charge electricity with all the power consumed in its manufacture. My business is to make cotton cloth; and, if I have got any power, I can profitably employ it in that way, and I don't see why I should give it to the electrical light people for nothing. I propose to charge them with all the power they get, and, indeed, everything else. And I have been, I say, unable to make any figures which, with the ordinary use of artificial light in mills, assuming it to be one hour a day, taking gas at $1.60 a thousand as it is furnished to us in Lowell, I have been unable to make any figures which prove to me that there is any very decided economy in the use of electric light. I have also two systems of incandescent lamps in use to a partial extent—one the Edison and the other the Maxim so called; that is, the incandescent light furnished by the Weston Company of New England, and which I believe is exactly the same lamp as the United States lamp which Mr. Lippitt has in use. They give very nice lights; and it is only fair to say that with the proposed change which the Edison Company are talking of instituting in my place, that, if they can meet the conditions which they propose to meet, they would be able to beat gas at $1.60. Up to this time I don't think that they have been able to quite do that. It has been touch and go; but, if anything, the gas has had a little the best of it. The collateral advantages, however, are very great; and what their pecuniary value is going to be, of course it would take more experience than I have had, or almost any one, in the use of electric lights, to determine. When I say the collateral advantages, I mean the improved quality of the atmosphere, the absence of heat, and I think a decided safety from fire. As Mr. Woodbury has pointed out. electricity is like a good many other agents that we employ about our mills, and if we don't take care of it it will do us a mischief; but I don't see that it is any more dangerous than it is to run steam about in pipes, as we are compelled to do, at very high pressures, or acids, as one does about a print works, all of which, if it was not looked after, would work you a very great damage. I don't think, with an electric plant properly put in in the first place, that there is very much reason for apprehension on the score of danger. I think the first lamp that was put into my mills was put in with uninsulated wires, and it was before the underwriters had tabooed that sort of thing, and we were all very green about it; and the people who put it in—a New York concern—put the plant in in that way, and we ran it for a year or more with perfect success as regards the light. We have since insulated it ourselves by wrapping it with paraffine cloth, and it is running to-day the lamps of the Fuller Company. It is a small machine. I put it in my packing-room, where color was also a matter of importance, and I put it in without any regard to the question of

economy, but simply to be able to perfectly distinguish colors and sort goods. I don't think that there are any other points that have been left untouched. Everything seems to have been so completely exhausted that I will not take any more of your time.

Mr. CHARLES L. LOVERING—I do not see that I can add anything to what has been said. I am using in one room fifty-four Brush arc lights. Each light displaces seventeen and a half burners. I would use in that room nine hundred and forty-eight gas-burners—a burner to a loom on colored work. I thought up to a year ago, that there was nothing to be saved in the way of expense; but I am rather of the opinion now that there is a saving over gas. I pay for gas $1.75 a thousand. I do not charge against the electric lighting any interest upon the steam plant. Leaving that out, it seems to me, unless I am mistaken, it figures something like a dollar a thousand for gas; but of course all the interest upon a large steam plant should be charged. I have a surplus of power in that room, and I don't know that I put a shovelful more of coal under the fire; yet I am charging to the electric light account four pounds of coal per horse power for every hour I use it. It is a one-story mill, lighted sufficiently from overhead. The lamps are thirteen feet from the floor, and I get a very perfect light. As has been said by Mr. Kilburn, of New Bedford, I am never at a loss to find persons to work in the room; they are always ready to go there. On the floor below, which is only twelve feet high, I am running eighteen lights, and an arc light there will not displace more than twelve gas-burners. But where the room is high, and the rays are thrown so that they will cover more floor surface, an arc light will displace more burners. The space covered by these fifty-four lights is something like fifty-four thousand five hundred feet.

EDWARD ATKINSON, ESQ.—It may be expected that I shall have something to say in this debate with respect to electric lighting and its possible dangers; and perhaps you may wish me to add a few words as to its merits.

In making up my own mind as to the policy which the Boston Manufacturers' Mutual Fire Insurance Company and other mutual companies ought to pursue in the matter, I have been obliged, as I have said previously, to study a subject of which even scientific men know little, and of which I knew nothing; treated in technical terms which have themselves been changed by joint consent of electricians during the progress of the investigation. It has therefore been necessary for me to delegate to Mr. Woodbury, who is well prepared by his previous scientific training, the duty of making a complete investigation of the whole subject; and, during the last year, his work has mainly been devoted to the survey and inspection of electric lighting plants in the risks insured by us, including also a full inspection of the different works in which the different kinds of mechanism required are manufactured. In this investigation he has had the hearty co-operation of all the reputable patentees and makers of electric apparatus; and it is a somewhat singular fact, that the rules for the introduction of electric lighting plants, and for their use, which were adopted by the mutual companies with the co-operation of all the reputable electric light companies, have now been standing six months; have been adopted by stock underwriters, with such modifications as the conditions of miscellaneous hazards require; have been virtually copied by the Society of Telegraph Engineers and Electricians of Great Britain; and have required neither alteration nor substantial addition since they were first issued.

In respect to the mechanism for the development of this force known as electricity, it may be said that the art of generating this power is very old, and that mechanism for this purpose, of a very perfect kind, has been long in use in the application of the dynamo-electric machine to electro-plating. There are now a considerable number of dynamo-electric machines; perhaps not as many varieties as there are of turbine water-wheels, but there is substantially the same choice. You can pay a high price for a very perfect machine, like the Boyden turbine, from which you may develop ninety or ninety-five per cent. of the power applied to its movement; or you may pay a less price for a machine which will give you the equivalent of a turbine water-wheel, rated at seventy-five per cent. of the actual weight of water applied.

There are various patents upon different kinds of mechanism used for this purpose; but they are upon mere details, as far as I can learn, and there are as many ways of constructing an efficient dynamo-machine as there have proved to be many ways of constructing effective automatic sprinklers and turbine wheels.

In respect to what is known as the arc system of lighting, it may also be said that the principle of the arc lamp is well understood. The carbon candles are now made substantially pure, and very nearly if not quite homogeneous. There is little to be done in improving the arc lamp, except in the clock-work by which its motions are actuated. The arc lamp is, perhaps, most suitable for use outside the factories, or in large places like dye-houses, iron-works, and rolling-mills; but it is probably not as well adapted to the inside work of the textile factories, as what is called the incandescent lamp.

There are three well-known varieties of so-called incandescent lamps, in each of which a film of carbon is interposed in the current of electricity causing friction or resistance; developing heat in the carbon, and, as the secondary effect, developing more or less light. These films of carbon are enclosed in glass globes from which the air has been substantially exhausted.

The question at issue in deciding upon the respective merits of the Edison, the Maxim, and the Swan light, is,—

1st. The durability of the film of carbon, and its capacity to bear the electric current without being destroyed.

2d. The durability of the lamp as a whole, including the glass globe.

There is probably more room for improvement in the carbons for the incandescent system, or for the substitution of some other material and in the making of these lamps, than in any other part of the system of electric lighting. The incandescent lamp may not give as much light in proportion to the power applied as the arc light will give in certain directions or lines of light: but the incandescent lamp can be placed where the light is most available; and more light can probably be developed of a useful kind, or better adapted to specific purposes, in proportion to the power applied, than from the other system.

As I have said, the whole subject of electric lighting is shingled and plastered over, and obscured by the claims of various patentees; and the relative value or validity of these patents can only be determined when they have been carried through the courts. Every user of every kind of light should secure a sufficient bond of indemnity to protect him against the litigation which has begun, and the possible damage which may ensue. Under what has been called the "*electro-mania*," various substantial corporations and many wildcat companies have been organized; and some of them have been floated at fancy prices for the stock. If it were within the province of an underwriter to issue policies of insurance upon the profits which are expected to be based upon a share in patent rights in electric lighting, I think it would be quite safe to issue policies of a kind once offered to me, when I was the clerk of a manufacturing company, upon a cotton mill, which I submitted to one of the oldest stock-underwriters in State Street for insurance. I unfolded the plans, and described the risk; and he cheered me by saying that he would issue a policy "at a very low rate of premium." As the mutuals had then just begun, and the usual stock rates were very high, I was much encouraged by this remark; and, as I prepared to draw my application, he said, "Perhaps you misunderstand me, Mr. Atkinson: the low rate will be upon a policy assuring you that the mill will be consumed by fire within a reasonable time. We will not insure you against loss by fire at any price."

I think it would be pretty safe to issue policies assuring the large portion of those who take stock in patent rights upon electric lighting, that they will make no profit out of them. The contest will be bitter, but the end is probably not far off when the manufacture of electric apparatus and the use of the electric light will come down to a commercial basis with a fair commercial profit to the best companies making the apparatus, and a fair commercial profit to those who apply this apparatus to use.

My conclusion individually is this—that an incandescent light is the true factory light of the future; that it is the safest light which can be put into a mill, the best light to assure perfect work, and the best means of lighting a mill if re-

gard be given to the conditions of health of the operatives. As a mere measure of economy and profit, I have been assured by skillful men who have made use of the electric light in their own factories, that, even if it should cost much more than gas, they would not give it up, because under its use they can secure more and better work from their machinery, owing to the more vigorous condition and vitality of the operatives who attend it.

While I say that I consider the incandescent system the safest, I do not object to the use of the arc lamp under proper safeguards. I consider either system better and safer than gas or oil, if put up properly, and operated under constant supervision, subject to the rigid control of a factory yard. It is not to be assumed that there is no danger of fire from the incandescent light; this force called electricity cannot be applied without danger; but all these dangers, as Mr. Woodbury has stated, are of a sort easily avoided, and the dangers from the incandescent system are more surely avoided than the dangers from the arc system of lighting.

In what I have said about danger, you will observe that I limit my observations to the factory yards of which you have charge. The dangers from the rapid extension of electric light wires in cities upon combustible roofs do not rightly come into the present discussion.

I am profoundly convinced, however, that the day is not far distant when even in our dwelling-houses we shall safely use the electric light and power, and when we shall draw gaseous fuel only from the pipes from which we now obtain our illuminating gas. This is the impression which the developments now being made in each of these directions make upon the mind of one who, without scientific training, must yet consider each application of electric science in the conduct of his business.

GUNNERY EXPERIMENTS AT SPEZZIA.

From the "London Times."

THE year 1882 will be remarkable in the history of artillery science, because for the first time steel and compound armor have come into competition with guns of the highest calibre, and have shown their power of resisting any but almost fabulous blows. At the same time, a gun has been produced capable of dealing such extraordinary blows, while the whole process of loading and laying the piece can be carried out by a single hand, no stronger than that of a lady. England and France have vied with each other in constructing the plates. The breech-loading 100-ton gun is English. We shall presently attempt to give some idea of the method of working the Armstrong 100-ton breechloader, some of the features of which are quite new in the history of artillery. But before doing so, it should be noticed that the total abolition of trunnions has so narrowed the space occupied by each gun that two of them can be easily and comfortably worked in a turret if necessary, though the present arrangements designed for the "Italia" and "Lepanto" are intended to fire *en barbette* from behind a breastwork. The Germans being confronted with the difficulty occasioned by the width of guns, have solved it by placing only one gun in each turret. Mr. Rendel, formerly of the firm of Sir W. Armstrong, and now at the Admiralty, has solved the same problem by his designs for the mounting of the 100-ton breechloader. Instead of throwing away a gun, he has narrowed the space it occupies, and placed the whole of the loading and laying arrangements safely out of the way, so that there is plenty of room in a turret for two guns if necessary. The 100-ton breechloading gun is composed for more than half its weight of steel, the rest being wrought iron. The inner tube and the nest tube which embraces it are both of steel, and on the exterior of the gun are rings of the same material. It is by far the strongest piece of ordnance ever constructed by the Elswick firm. Its principal dimensions are as follows:—Length over all, 468 inches; length of bore (26 calibres), 442 inches; length of rifling, 335.4 inches; diameter at muzzle,

33.3 inches; diameter at breech, 65.5 inches; diameter of bore, 17.0 inches; diameter of powder chamber, 19.5 inches.

One of the most interesting points with regard to the gun is the method of mounting it. The usual trunnions are entirely absent. The gun lies imbedded on a sort of sledge carriage, which is a mass of steel, weighing about 14 tons. Projecting rings, which form part of the gun, rest in grooves, and prevent any backward or forward motion of the piece on the carriage, and rotatory motion is prevented by strong steel straps. Thus the gun and carriage are securely bound together, having their axles parallel, and recoil together in the same direction. The carriage rests and slides upon the planed surface of two cast steel beams of about 10 tons weight each. They are held together by the recoil press, and their front ends pivot vertically on a massive hinge. Thus the axes of the gun, the carriage, the recoil press, and the slide are all parallel, whatever the elevation, and the difficulty of restraining the rotatory motion caused in other systems by recoil is completely got rid of. The whole weight is taken by two powerful hydraulic presses, which work always together, being acted upon by one common supply pipe. If the muzzle of the gun is to be elevated, the hydraulic rams sink, and the slide, pivoting on its front end, is lowered in rear, carrying with it recoil press, gun and carriage. The reverse takes place when the gun is to be depressed. By this simple arrangement a host of difficulties are at once eliminated, and some terrible strains removed from the system. And not only is there the advantage of harmonious recoil, but the pivoting on the end of the slide enables the gun to be fired through a very small port, which it would fill almost completely. This is an improvement on the "Inflexible," where it has been found necessary to attach to the muzzle of the gun a steel shield formed of two-inch bars, to guard the port from the fire of rifles and machine guns.

The loading arrangements are also extremely simple, and present some features of novelty, besides the mere fact that the gun is loaded at the breech. With the exception of bringing up the ammunition and ramming, which are performed by another hydraulic apparatus, the whole business of opening and closing the breech is performed by two levers close together, which are worked by one man. He cannot make a mistake, for nothing can be moved out of its proper order, and whatever position a lever may be in at the end of its last movement, the next act is performed merely by pushing or pulling the lever to the opposite side. One pair of levers works the whole breech-closing apparatus, prepares the gun for loading, or opens the breech after discharge. Another pair of levers runs the gun out and in, and elevates or depresses it. It is impossible to run it back or forward too far, and the whole mighty mass of metal may be managed by the hand of a lady, who cannot possibly make a mistake. If she touches a lever it must be to pull it back or thrust it forward from the position in which it then lies, and no movement that can be made will set anything wrong. All the movements involved in opening the breech, withdrawing the breech screw, replacing and closing the breech, can be performed in less than one minute. No damage can be done in the heat of action, and the gun cannot be fired till the operation of loading and closing the breech has been completely performed. The whole process seems like magic, so simple is it, so easy, and so certain. The most inexperienced person can learn the movements in five minutes.

It is almost impossible to make the process of loading and laying the gun understood without the aid of drawings, but some idea of it may perhaps be given to those who have a knowledge of mechanics as applied to artillery. The hydraulic pumps are worked by a small steam-engine, which is governed in its rate of work by the pressure of water produced. It never ceases work, but when no movement is required of any of the parts its action is feeble and only keeps up a certain normal pressure. But if any motion of the system is required and the touch of a lever opens the way for water to create that motion, the engine instantly sets off briskly and continues to act till the cessation of movement tells it that its services are no longer required. It then drops back at once to its slow and feeble action. The engine is seated on a tank, from which the pumps draw their water, and to which the water is returned

after being exhausted from the various cylinders and pipes. Behind and across the breech of the gun, but entirely separate from it, is a slide-bed similar to that of a lathe, and on this bed moves a saddle which carries the loading tube and a rest for the breech screw when drawn out of the gun. Now, let us suppose that the gun has been fired and requires to be loaded. By touching the levers for elevating and running back, the gun is brought into the loading position exactly. It cannot go too far in either direction. A touch on another lever brings the saddle into its proper position, unlocking and turning the breech screw as it comes. A touch on the third lever brings up a piston from the rear and makes it engage a catch in the breech screw. The same lever moved in the opposite direction draws out the breech screw upon a bed made to receive it on the saddle, which is then drawn out of the way by a reverse movement of the lever which brought it up. As the saddle moves side ways, that part of it containing the loading tube comes into position exactly behind the rear end of the bore. The small piston which withdrew the breech screw now pushes the loading tube into the gun, the object of the tube being to protect the threads of the female breech screw from abrasion by the shot. All is now ready for loading, which is performed as in the muzzle-loading 100-ton gun. The projectile and its two half-charges are always kept ready on trolleys, which rise by hydraulic pressure from their places in the magazines, and arrive between the hydraulic rammer head and the breech of the gun. Other levers thrust them forward into their places; the loading tube is withdrawn and the breech closed by a reversal of the different movements just described, which do their work more quickly than the description of their action can be read. The breech of the gun cannot be moved till all is complete, and the piece cannot be fired unless the breech is accurately closed and locked to prevent its opening.

When mounted in the "Italia" and "Lepanto," for which they have been designed, these 100-ton breech-loaders will be *en barbette*—that is, they will be elevated so as to see over the top of the battery as in the French ships, but there will be this advantage, that, whereas in French men-of-war the men working the gun are exposed to the fire of small arms, machine guns, and shrapnel, not a single man will be exposed in the Italian ships. The whole of the machinery, which, though elaborate to describe, is simple and massive in reality, will be under an armored deck. The only break in protection by the deck is the portion through which the rear part of the gun descends, and that will be covered by the mass of metal above it composing the gun. In the French ships, gun and gunners are equally exposed. It needs no technical knowledge to understand how valuable this advantage is.

Having now described the gun, the method of mounting, and the progress of loading, it remains to tell what the piece has actually done, and to explain why such of huge weapons are required for the ships the future. The table on next page shows the rounds lately fired at Spezzia, but it should be remarked, first, that the strength of the gun is calculated to bear with safety a pressure of 29 tons per square inch, while the highest yet reached is only 16.5 tons; secondly, that though the greatest charges ever yet fired in a gun have now been much exceeded, the powder chamber has room for a much larger charge than any used at Spezzia; and, lastly, that there is an evident intention on the part of the Italians to try even more powder, experimentally at any rate. Indeed, it is not improbable that they may, as they did with the muzzle loading 100-ton gun, increase the charge till it passes the limits of safety, for the sake of experiment. Such a course would be interesting to scientific artillerists, but might damage the confidence of the Italian navy in its guns and the Italian people in their navy. It is also probable that the breechloader will be fired at the Schneider steel plate, which is still untouched, and the question will be decided whether the solid 19 inches of steel will resist the impact of a projectile which has a total energy of about 46,000 foot tons.

With regard to the above table, it is to be remarked that both Fossano (Italian) powder and prismatic (German) powder were provided for the experiment, but, finding that there was little to choose between them, the committee decided to adhere to their own explosive. Rounds 13, 16, and 18 were fired with almost the full elevation possible—namely 11 deg.

No. of round.	Powder charge.		Projectile weight.	Velocity—Feet per second.	Pressure in bore of gun—foot-tons per square inch.
	Weight.	Description.			
1	496	Fossano.	—	1433	10.9
2	551.2	"	—	1496	11
3	551.2	"	Chilled. 1974	1512	11
4	606.3	"	Do. 1942	1593	11.35
5	606.3	"	Do. 2001	1609	11
6	661.4	"	Do. 2005	1676	12.5
7	661.4	"	"	1686	12.4
8	716.5	"	"	1767	13.6 14.1
9	771.6	"	"	1833	16.5
10	716.5	"	"	1761	14.5
11	496	Prismatic.	"	1423	9 3
12	551.2	"	"	1506	10.4 10.3
13	551.2	"	"	Not taken.	11 6
14	771.6	Fossano.	"	1831	16.4
15	606.3	Prismatic.	"	1607	12.8 12.5
16	606.3	"	"	Not taken.	13.5 13.6
17	716.5	Fossano.	"	"	13.8 13.7
18	771.6	"	"	"	15 9 16

50 min.—and therefore did not register their velocity because they passed over the screens instead of through them. The range out to sea was evidently enormous, but formed no part of the test trial, and was therefore not measured. The shot was 18.4 secs. in the air before touching the water. Round 17 was fired with almost full depression—namely, 3 deg. 50 min.—and plunged into the sea below the screens, throwing up a magnificent column of water about 100 feet high.

The results of these experiments have shown that guns weighing 100 tons can be manipulated with greater ease by means of hydraulic power than the 12-ton 9-inch gun without it. The whole apparatus takes up very little room, and is perfectly simple in character. There is no reason why a gun of 150 or 200 tons should not be manipulated with equal ease. If it be asked why such monstrous pieces of ordnance should be used at all, the reply is that the condition of the controversy between guns and armor-plates has been completely charged by the construction of steel and compound armor. It has now become necessary to give the idea of perforating the armor of the future with anything less than such a piece as the 100-ton breechloader, and the power of guns against armor must now be estimated by the total energy of the blow delivered instead of by the old calculation of the energy per inch of shot circumference. In the days previous to the trial of the big breechloader, the muzzle-loading 100-ton gun was fired at two English compound plates, 19 inches thick—one made by Cammell and the other by Brown, and at a Schneider steel plate. The English plates were not sufficiently bolted to the backing, and therefore came to pieces more easily than they ought to have done. Moreover, from want of machinery designed to roll such very thick plates they had not been worked down so much as they should have been and will be in the future. The first round fired at each plate was with a charge of 328.5 lbs. of Fossano powder, less than half the highest charge fired from the breechloader. The striking velocity was in each case about 1,220 feet, and the total weight a little above or below 20,000 foot tons. In no case was the plate perforated, nor did

any serious injury occur to the backing, though the shot would have gone clean through a 19 inch wrought-iron plate. A second round was fired at each plate with a charge of 478.4 lbs. of Fossano powder, giving a striking velocity of 1,560 feet approximately, and a total energy of about 33,900 foot-tons. These rounds would have pierced a 25-inch wrought iron plate, yet they failed to perforate any of the three pieces of armor opposed to them, though the steel plate was cracked badly and the two compound plates were broken to pieces. In all three cases the backing suffered, but less in the case of the steel plate than of the others. Against the Schneider steel plate was now fired a Whitworth steel projectile, with a striking velocity of 1.538 feet, and a total energy of rather more than 34,000 foot tons. The plate was broken up and the backing dashed in by the total force of the blow, though the shot itself had been rejected, and lay defaced and distorted, among the débris at the foot of the front of the target. At these experiments were present experts from the principal nations of Europe, and among them all there was but one opinion, namely, that the object of the artillerist in designing ships' guns for the future must be to endeavor to gain, by means of large calibres and enormous projectiles, the greatest possible total energy of blow. Plates of such quality as those tried at Spezzia cannot be pierced, or, indeed, destroyed in any way by projectiles from moderate sized guns. The side of the ship must be driven in by the single blow of a huge projectile delivered from a monstrous piece of ordnance. This is what the future seems to have in store for us, and it can hardly be said that the prospect is satisfactory. It is necessary to correct a statement which appears to have got abroad, that in the experiments against the steel and compound plates the 100-ton breechloader was used. Not so; the gun was the 100-ton muzzle-loader, but it was generally understood at Spezzia that the breech-loader will be fired at a new 19-inch Schneider plate, which is already on the practice ground.

THE SUPPOSED NEED OF A NEW STYLE OF ARCHITECTURE.

By SAMUEL HUGGINS.

From "The Builder."

A FEW considerations against the often heard and even lately expressed wish for a new style of architecture, our great desideratum according to more than one eminent man, which I have not seen urged before, as they may have a tendency to promote that contentment with our old styles which is essential to progress, are here offered.

The advocate for the invention of a new style should be asked: Is there any hope that a new style could be invented equal to or bearing any comparison with the old ones? Or, by what other entirely different or absolutely new elements St. Paul's Cathedral, the Louvre, or Grimani Palace would have been equal to what they are? Supposing our English Palladio, instead of studying ancient and modern architecture in Italy and devising mosques and courtly pageants at home, had devoted the many years so spent to the invention of a new style, and employed it in his design for the Whitehall Palace; and supposing Wren, abjuring both that and the old styles, and resolving to have his great work absolutely original, had depended on geometrical and abstract beauty of form in voids and solids with what moulding and panelling, pronouncing of joints, and decorating of courses he could devise, what would have been the result in each case? Nay, what would the mighty Buonarotti himself have made of St. Peter's had he followed either of these courses?

I do not believe a door or window opening could be so beautifully framed and fashioned by any other elements as

by members of the columnar ordinance. I am not here speaking of window-tracery, in which the Gothic is pre-eminent.

Columns or pillars of some kind would be deemed essential to a new style; but would any other type of form be equal in beauty to the Græco-Roman? Some additions might possibly be made to it, as the bracket-capital, for instance, but it is as difficult to imagine columns with any pretensions to beauty, of a different type to the Doric, Ionic, and Corinthian respectively, as to imagine handsome men and women with other features than eyes, nose, and mouth, or with these in different relative positions.

But the great argument against the course in question is not the difficulty or impossibility of producing a new style equal to the old, but that no new style would be generally accepted. The greatest objection to a new style would be that it was new. I believe if a new style were invented, based on a deep study of nature and geometry, and perfectly beautiful, it would come still-born into the world. A building in such a style would be an architectural monster, with which we could have no sympathy. It could not come home to men's bosoms like one on which their eyes, and through them their whole souls, had long gazed. Its absolute originality would be a fatal defect. There is an instinctive feeling in the human breast hostile to the introduction of a new style. The same sentiment of veneration that disposes us to reverence ancient birth too often more than virtue itself; or, if I may quote in so serious a connection the passionate exclamation of *Hardcastle* in "She Stoops to Conquer," to love everything that is old—old friends, old times, old manners, old books, old wines—the feeling that leads the dying to "cast one longing, lingering look behind," inclines us to prefer old styles of architecture to new. "The mind," says Sir Joshua Reynolds, "can bear with pleasure but a small portion of novelty at a time. The main part of a work must be in the mode to which we have been used . . . . where all is novelty the attention and exercise of the mind is too violent." And now we are so rapidly leaving other traditions of the past behind us through the material progress of the present age that there never was a greater need to cling to our ancient architectural ones.

"The past fills the urns of the future at the fountain of life," and the new in architecture must flow out of the old as it has ever done. Connection with the past was never cut by any nation at any period of the world. There has been no stopping and no beginning again—inventing a new style, and abandoning the old one for the sake of novelty. The styles have merely changed—changed spontaneously by adaptation to new circumstances; as the Byzantine and other contemporary styles in various countries changed into the different Saracenic styles; in which case the new circumstances were the old styles falling into the hands of a new race holding a new religion, with the peculiar well-known prohibition to represent the human form.

Even the Greeks who, in such a matter, must be held above suspicion of error, did not invent an absolutely new style, but developed one out of the Egyptian and Assyrian; and the styles we are now using, whether Classic or Gothic, may be said to have a genealogical relation to the two oldest styles in the world—to have, so to speak, Egyptian and Assyrian blood in them. There are so many links connecting our present practice with the whole history of architecture, and London and Paris of to-day with the buried and lost cities of antiquity, so that every genuine new edifice is related to every other in the world—related as no poem, or picture, or statue, is related to its kind. Great books make foot-paths for the thoughts of nations, but they are not so linked in a descending chain from age to age as great typical buildings—examples of styles—through which the last erected columnar door case or portico may prove its descent from the temple of Karnack.

The introduction of the old styles into America and Australia has assimilated those new worlds to the old countries of Europe more, perhaps, than anything else.

There is immense advantage æsthetically in retaining the old style. The classic styles, for example, are so many lines of truth and beauty coming down to us from dark antiquity and becoming brighter and brighter, giving every new building the advantage of its predecessor

by the accumulating wealth of the style from the minds of the practitioners in all ages. Architecture differs in this from all the other fine arts: a piece of sculpture or a picture may have no mind beaming from it but its author's; but a modern neo-classic building of merit is not only an exponent of the mind of its designer, but is also, through its component elements, an embodiment of Greek and Roman genius, and has more power or virtue than its author put into it. The most interesting creature of architecture is that in which the old style is fully adapted and appropriated to the situation and purpose. It has not only an æsthetic interest, but an historic, while it is instinct with the mind and heart of the designer, and adorns nature, it is breathing of other days. It has come legitimately into the world, and is a legitimate offspring of art.

A new style is, therefore, not called for by the eternal law of intellectual progress under which the world lies, and of which we hear so much. That law is best obeyed by carrying on the old styles and handing them down to our successors enriched and exalted; in doing which conservatism and liberalism are alike served.

It appears evident to me that no new style that would respond to our multitudinous wants could be so completely based on nature, and so beautiful at the same time, as the columnar system; for the column is the natural pillar of necessity moulded, adorned, and raised into an element of art. With the entablature, which includes the frieze, designed as a girdle or zone of illustrative sculpture, and the modern pilaster, an echo of the column, and the Italian baluster or miniature column, it composes a system the possible viriations on which are all but infinite; and which may well be called, as it was by Goethe, a second or ideal nature.

The development and perfecting by the Greeks in the Grecian Doric, more especially of the Parthenon, by the generalized imitation and idealization of nature, of a combination of forms constituting the columnar ordinance, of such beauty, elasticity, and adaptability, and such power to charm a building into architecture, acting on it like an incantation, that it has become, in whole or in part, the omnipresent and everlasting concomitant, the bones and muscles and nerves of civil architecture, was one of the most fortunate operations of genius, and important events in the history of art.

That it has been misused, and not always applied structurally—wrought into the warp and woof of the building—is its misfortune and not its fault. It reminds me strongly of the identity in the fundamental principles, pointed out by Dr. Buckland, of the construction of animals and plants, and the uniform adoption of analogous means to produce various ends, with so much only of departure from one common type of mechanism as was requisite to adapt each instrument to its own special function, and to fit each species to its peculiar place and office in the scale of created beings.

It determined the main course and history of architecture through all ages and lands. The Parthenon in which it appeared in perfection is the Iliad of architecture.

No architect, I think, should need anything more systematized than the Græco-Roman architecture, a glance at which by a man of any imagination must be sufficient to show its capabilities and susceptibilities, and its proper application, without any other guide or help from the mode or manner of any particular period or place. He who should wish a more marked-out or definite road must be indebted to the great Italian architects, who, guided by the analogy of nature and their own powerful instincts, not only recalled the architecture of their forefathers out of the ruined baths, palaces, and temples, as from chaos, and organized it into an exhaustibly copious system (more copious in combining harmoniously the two principles of construction, the beam and arch, than either Greek or Gothic), but bent it to almost every purpose that modern European life and institutions could require, and showed different modes of using the anciet orders.

The elements of this style, taken by architects into different countries of Europe, as seed is carried by the winds we know not whither, producing varieties of the same plant according to the climate and soil, have in different countries given birth to different varieties of the style, and struck deep root here in Eng-

land; and our Anglo-Italian has been already fully acclimatized and embodied by Inigo Jones, Wren, and their followers, in structures of various classes which stand like finger-posts pointing in every direction.

There is not only any amount of scope for genius within the limits of this style, but the style, beautiful in itself and prone to beauty, has the power of inspiring forms and images of beauty and sublimity. It suggests beautiful ideas, and expands and intensifies those of the architect. No poet ever had so beautiful a language in which to express his ideas as the architect of the present day. Some poets have had almost to create the language in which they wrote. Dante, for instance, had to purify, and polish, and fit for his "Divine Comedy." the popular dialects of his country, and all but create the after-language of Italy. But the condition of the architect is the very reserve of this. He has a rich language, the accumulated stock or fund of the art, that no individual Cadmus, however inspired, could have composed—a language invented by Egyptian, Assyrian, Athenian, Ionian, and Roman, and reorganized into the most copious and elastic system ever framed, by a constellation of men who may each of them be said to have bestridden the world of art like a Colossus, and who touched nothing that they did not exalt.

No introduction of a new constructive principle, as the tensile, into architecture can supersede this style in favor of a new one A new decorative style is necessary to that class of buildings, which are chiefly of iron, and in which the great leading constructive principle is the tensile, a search after which is laudable as a search after truth; but the introduction of the tie along with the arch and beam into stone buildings will not overthrow the laws of stone architecture, and generate the style of the future, as I have seen it somewhere asserted. It can only dictate the style of a class of buildings of which the railway-shed is a prime example, in which the tensile covering is fully displayed.

With such a system as this acclimatized Italian style, which has been ruralized and embodied in villas and mansions of every grade, and shown itself capable of application to cottages and the very humblest residences, and to brick construction as well as to stone, we need no new style nor any backsliding to a past period, however refined, for models. In view of its all-sufficiency I cannot imagine how any want could have been felt for the style that prevailed in the reign of Queen Anne—a period which, however, otherwise interesting for richness of literature and eloquence, was certainly not the Augustan age of art. When the painter is taught to eschew the imitation of ordinary nature as unfitted to raise the conceptions or warm the heart of the spectator, and to imitate a more perfect image of beauty fixed in his own mind, approaching to that central form of the species or class every deviation from which is deformity, is not the imitation by the architect of the imperfect works of man of a non-artistic and limited period a still greater mistake and degradation? Is the style of Queen Anne's day the central or ideal form of architecture?

This new practice has been called designing. I doubt not its leaders will find some scope in it for the exercise of their taste and skill; but it is not properly designing; and in the hands of the younger men it will be imitation of single buildings, or copying, resulting too often in caricature.

A building, it is true, might be consistently copied, though I never saw it suggested—as a great sculptor would copy a human form with correction and idealization, for by so doing a man with a little artistic power could produce an original work of art greater than its prototype. But we do not hear of any operations of this sort in the Queen Anne school.

The fact of their narrowing themselves to a period exposes them to the suspicion that it is for imitation merely of the picturesque gables and dormer windows (which, by the way, are well-nigh obsolete features, come of the obsolete steep roof) of certain old buildings, ignoring the epochal character and true nature of architecture, which, like Nature herself, works from within outwards, and clothes the architect's preconception with material form of true expression and character, as far within the power of architecture or sculpture; and which is as essential in architecture as expression of

the character and passions of men in an historical picture. The movement in question appears to me to be a deviation from the true path of architectural progress, to save the labor of thinking and designing, and to evade the difficulties of art. Its authors resemble the two characters, Formalist and Hypocrisy, in the "Pilgrim's Progress," who, instead of ascending with Christian the Hill Difficulty, turn, for greater ease, each into a by-path on either hand, leading far away from the Celestial Gate.

It has no right to the name of a revival, or bringing to life, for it can have no artistic life in it. Totally unlike the Italian revival, which was a resurrection of the Roman in a new and more radiant form—in its general character it will be architectural mimicry of the air and manner of another age, than which there is nothing more contrasting with the life-giving operations of true art. There is no object in nature so devoid of interest as the produce of such operations. It is neither new nor old. It has proceeded neither from head nor heart. It is dead—

"Dead as old Chaos before motion's birth."

A preference of brick to stucco seems to be some way concerned in this movement. But the claims of brick depend in a great measure on its color—an important matter, especially in country or suburban houses, which should make harmonious contrast with the scenery around. Brick, as it has generally appeared among us, is a mean material, and not so fit to do the honors of architecture as could be wished. I allude to the London bricks of the clay-colored hue, and to the generally harsh crude red brick. But bricks might be colored to be worthy of any situation or purpose, and capable of adding grace to the finest natural scenery. I remember, in some of the older houses about Liverpool, bricks of a pale orange-red, which is the most beautiful of all colors, and the chief ingredient in the richness of autumnal scenes, and infinitely superior to the red stone hue, which can only be redeemed by the tonings of time, or, for the moment, by sunset glows, when it becomes a rich orange. Bricks of this color, combined with warm grey stone dressings, are fit for any building. The light stone is valuable for contrast with the generally dark foliage of the landscape, mention of which reminds me that the designer of country residences, to become part of the scenery of nature, which is sometimes such as no landscape painter has ever done justice to, has a difficult task. He will be best fitted for it who is conscious of those delicate relations which exist between the beauties of nature and his deepest emotions. But this is somewhat digressive.

If love of the picturesque had aught to do with the "Queen Anne" movement, let me say that picturesqueness is not a legitimate aim in architecture. A dwelling-house is to be made as beautiful in form and composition as due attention to its purpose and expression of its purpose will permit. If that leads to a picturesque outline, it is well—and Gothic being more in sympathy with the arboraceous forms of nature, will be more picturesque than classic. But picturesqueness is a quality not to be sought. It arises from fortuitous forms and colors, the result of sun, rain, wind, time, change, and accident, which are the creators of the picturesque both in nature and architecture. The effect of the latter agent, accident, is strikingly seen in the picturesque disposition of mountain chains and groups, which have been caused by repeated throes and convulsions of nature. Beauty, grace, grandeur, sublimity are the qualities to be aimed at in architectural design according to the class of subject; not picturesqueness which, indeed, is not a term in architecture, but in painting.

The follower of the Queen Anne style is not in the way on which to acquire the reputation of being a man of genius, which, according to Sir Joshua Reynolds, is the highest ambition of every artist; nor to gratify the higher and truer ambition of enlarging the boundaries of his art and raising it to its highest dignity. He is moving, in fact, in the diametrically opposite course to that by which the Greeks achieved the Parthenon, by which they became the arbiters of form and exponents of the ideal both in sculpture and architecture. That the productions of this new school are a great improvement on the monotonous stuccoed blocks of the preceding period I readily admit, and credit the school with the introduc-

tion of some pleasing and much-needed qualities into their works, especially with what was a great desideratum in streets and suburban rows—individuality in the houses by which a man is not in danger of knocking at his neighbor's door or walking into his neighbor's house instead of his own. They have got into a better way; but what I must maintain is that it is not the right way. It is a by-path, not the broad highway of architecture—the way of truth and progress marked out and hallowed by the footprints of genius in all ages.

It is boasted that the Queen Anne style is likely to hold its own for some time to come, which is in reality an acknowledgment of its temporary character, for if it were true art it would hold its own, not for some time, but for all time to come. But men have a natural taste for truth, and only genuine architecture retains its place in their affectionate veneration.

They order this matter (of architecture I mean) better in France, if I may judge by glimpses of Parisian doings I have now and then had. But I see no reason why we could not order it better in England. Certainly English architects could if they would, *i. e.*, if they were true to their own gifts and did themselves justice. It should, however, be borne in mind that every sane educated man will not make an architect, which a man cannot be in the true sense of the word without imagination and art feeling, nor a very great one without sound judgment and pure taste also; a combination of qualities which nature seems not very fond of making up. Architecture requires a broader intellect in its professors than some other of the fine arts. A man may go farther, for example, in painting, with the mere faculty for drawing than in architecture. Drawing alone will make some sort of landscape painter, but it will not make an architect worth the name, even when guided by insight into the principles of art. The poet is born, not made; the architect is born and made.

The fully endowed architect is one who to vigorous reasoning powers, well disciplined in the mathematics, adds a lively imagination, with a good measure of æsthetic feeling or sensitiveness, which together is the most glorious gift of Heaven. He has also a due measure of æsthetic culture, by which alone can be developed all his faculties and sympathies, and which Schiller deemed preliminary to moral culture; and a memory stored with all literary and scientific lore. He has that sublime ennobling desire for truth which marks the philosopher, and appropriate, and sympathy with the aspirations and hopes of humanity, which characterize the poet; qualities which insure the utmost amount of both truth and beauty in his work, which will have all the moral power, purifying and elevating, which it is possible to enshrine in stone. As it is his highest glory to so far imitate his Creator as to breathe the breath of artistic life into senseless matter, so it is his highest ambition to have spectators and witnesses of his achievements, fit though few, among his contemporaries and posterity.

The highest gift, says George Eliot, the hero leaves his race is to have been a hero; and I may say the highest gift an architect could leave his profession is to have been an architect in this higher sense of the word,—to have shown the possibilities of his art, and the way to advance it, not by inventing new styles, but by illustrating, enriching, and expanding the old ones, by the creation of new designs; and shedding his own independent spirit to future ages.

This, however, is the high-water mark of the architectonic soul, which all architects cannot, and need not, reach; and I doubt not there are among the leaders of the profession in the metropolis and elsewhere men of sufficient natural endowment so to lead the way, at least, in which their juniors should go, that when they are old they will not depart from it. Let me say to all earnest students, young or old, in the words of Wordsworth on a still more important subject than the present one, but equally applicable to it:

> "Access for you
> Is yet preserved to principles of truth,
> Which the imaginative will upholds
> In seats of wisdom, not to be approach'd
> By the inferior faculty that moulds,
> With her minute and speculative pains,
> Opinion ever changing."

Let them work in sincerity and truth, which will secure sufficient of unity of

aim, uninfluenced by popular taste or fashion, and, however thin their ranks, their works will be like a little leaven in the mass of the national production, which, if it do not leaven the whole lump, may yet exert much influence upon it.

THE KINETIC THEORY OF GASES.

By HENRY T. EDDY, C.E., Ph. D., University of Cincinnati.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

II.

THE experiments of Andrews* upon the behavior of carbonic acid gas above the critical temperature are far more decisive upon this question than those of Thomson and Joule. In these experiments the pressures were carried to more than 100 atmospheres at different constant temperatures, in which $d\tau=0$ and (34) may be written

$$-d(pv)=\tfrac{1}{3}\Sigma(\mathrm{R}dr+rd\mathrm{R}) \quad . \quad . \quad (40).$$

which is equivalent to (40) as previously written. On the supposition in (36) this may be written

$$-d(pv)=\tfrac{1}{3}f(1-i)\Sigma r^{-i}\,dr \quad . \quad (41).$$

The following are the numerical results at the temperature of 48°.1C. in which p is given in atmospheres, and the volume v of the gas at one atmosphere is taken as 1000.

p.	v.	pv.
62.60	11.57	724.28
68.46	10.06	688.70
75.58	8.49	641.67
84.35	6.81	564.42
95.19	5.04	479.55
109.40	3.35	366.40

In treating this experiment as a compression dr is negative and both numbers (41) are then positive, while $rd\mathrm{R}$ is shown by the numerical results just given to be much larger than $\mathrm{R}dr$ and of opposite sign. Other results at temperatures nearer the critical temperature of 31°C. are perhaps more striking than those just quoted. The experiments of Andrews as well as those of Regnault and other physicists have shown conclusively that as the temperature of an imperfect gas is augmented it becomes more and more nearly perfect, *i. e.*, it approaches more nearly the state in which there are no intermolecular forces. Hence R is also a function of τ, and such a function that $d\mathrm{R}$ is negative when $d\tau$ is positive, from which it appears that in (34) the terms in $rd\mathrm{R}$ are in all cases of different sign from those in $\mathrm{R}dr$. In fact if the volume remains constant the terms in $\mathrm{R}dr$ vanish because dr vanishes. Hence combining this result with that previously arrived at we see, when temperature and pressure are taken as the independent variables, that since $\Sigma d(r\mathrm{R})$ is negative for increments of each of these variables separately it is so for both together and hence is so always.

8. RATIO OF THE SPECIFIC HEATS OF PERMANENT GASES.—Let κk be the specific heat at constant pressure and k that at constant volume expressed in ft. lbs.; then is κ the ratio in question.

Let dh be the amount of heat imparted during any infinitesimal change of state of a unit of gas; this heat is employed in raising the temperature by $d\tau$ say, and in performing work internal and external. If the work be denoted by dw, by the principle of the conservation of energy we have

$$dh=\kappa d\tau+dw. \quad . \quad . \quad . \quad . \quad . \quad . \quad (42).$$

Now if the change occur at constant pressure we have by definition of κk

$$dh=\kappa k d\tau, \quad . \quad . \quad . \quad . \quad . \quad . \quad (43).$$

Also, $$dw=pdv+\Sigma\mathrm{R}dr \quad . \quad . \quad . \quad (44).$$

in which pdv is the work of expansion against the external pressure, and $\Sigma\mathrm{R}dr$ is the work done against the intermolecular attractions. It is to be noticed that we have included no term in (44) representing the work done against interatomic forces within the molecule. But such a

* Phil. Trans. Land. R. Soc. 1869, p. 575, or Wullner's Exp. Physik, Bd. 3, S. 680.

term is not needed, for the variation of the atomic distances dr either vanishes or is so small as to make $\mathrm{R}dr$ negligible. For suppose a molecule to consist of a system of atoms held by elastic forces at certain mean distances, then those mean distances are not essentially changed by atomic vibrations, which alternately make the distances greater and smaller.

Now in (34) let $dp=0$, and by it (44) becomes

$$dw=\tfrac{2}{3}ak d\tau+\tfrac{1}{3}\Sigma(2\mathrm{R}dr-rd\mathrm{R}) \quad . \quad (45).$$

Now let $$\Sigma\mathrm{R}dr=bkd\tau \quad . \quad . \quad . \quad (46).$$

in which b is an extremely small positive numerical coefficient (which is zero for perfect gases) expressing what fraction the increment of the work performed against the intermolecular attractions is of the increment of the kinetic energy $kd\tau$. If we adopt the approximate value given in (36) we get for the last term of (45),

$$\tfrac{1}{3}\Sigma(2\mathrm{R}dr-rd)=\tfrac{1}{3}(2+i)bkd\tau \quad . \quad (47).$$

Now substitute from (47) in (45) and so obtain a value of dw, which can be itself instituted in (42). Also substitute in (42) the value of dh from (43) and divide by $kd\tau$; (42) then becomes

$$\kappa=1+\tfrac{2}{3}a+\tfrac{1}{3}(2+i)b \quad . \quad . \quad . \quad (48).$$

in which a needs further consideration. Let a' denote what fraction the increment of the mean rotary energy is of the total increment $kd\tau$ of the kinetic energy, and let a denote what fraction the vibratory energy (kinetic and potential) of the atoms within the molecule is of the same quantity. Since these together constitute the total increment of the kinetic energy, we have

$$a+a'+a=1 \quad . \quad . \quad . \quad (49).$$

But in the general case in which the molecule consists of more than two atoms, we have

$$akd\tau=a'kd\tau+\tfrac{1}{2}\Sigma d(r\mathrm{R}) \quad . \quad . \quad (50)$$

as appears from the fact that (34) is the precise value of the first member of (50), but as the intermolecular attractions cannot directly accelerate the rotary velocities by (29),

$$a'kd\tau=\tfrac{2}{3}d(pv) \quad . \quad . \quad . \quad . \quad (51).$$

is also exact and not approximate. Now substitute in (50) from (36) and (46), and divide by $kd\tau$.

$$\therefore \quad a=a'+\tfrac{1}{2}(1-i)b \quad . \quad . \quad . \quad (52).$$

Add (49) and (52)

$$\therefore \quad 2a=1-a+\tfrac{1}{2}(1-i)b \quad . \quad . \quad . \quad (53).$$

Substitute this value of a in (48),

$$\because \quad \kappa=\tfrac{4}{3}-\tfrac{1}{3}a+\tfrac{1}{6}(5+i)b \quad . \quad . \quad . \quad (54).$$

from which it appears that the work done against the intermolecular attractions dependent upon the terms in b probably have a very small influence upon the value of κ, but the vibratory motion of the atoms which is expressed by terms in a must in many cases be large, and consequently will, in such cases, exert a considerable influence upon the value of κ.

The experimental values of κ lie between 1.33 and 1.25. If we disregard the terms in b, the corresponding values of a are 0 and $\frac{1}{4}$. The larger values of a belong in general to the more complex molecules, and we seem here to have an experimental measure of the amount of the mean vibratory energy, kinetic and potential, within the molecule. If b is large in these gases, then a is for a given value of κ increased thereby.

In the case, however, in which the molecules consist of but two atoms each, we have by (30) the following equation instead of (52),

$$\tfrac{2}{3}a=a'+\tfrac{1}{3}(1-i)b \quad . \quad . \quad . \quad . \quad (55).$$

which combined with (48) and (49) gives

$$\kappa=\tfrac{7}{5}-\tfrac{2}{5}a+\tfrac{1}{5}(4+i)b \quad . \quad . \quad . \quad (56).$$

in which it is seen that b has a somewhat greater influence than in (54) while a has probably a much less influence, there being in this case but one pair of atoms to vibrate instead of three or more pairs, which will cause the value of a to be much smaller than previously.

The most probable experimental values of κ for diatomic gases lie between 1.41 and 1.39. In the case in which the molecules consist of a single atom each,

$$a'=0, \quad \therefore \quad a=1-a \quad . \quad . \quad . \quad (57).$$

in which case (48) becomes

$$\kappa=\tfrac{5}{3}-\tfrac{2}{3}a+\tfrac{1}{3}(+i)b \quad . \quad . \quad . \quad (58).$$

The experimental value of κ for the vapor of mercury, which is the only manatomic gas known, is 1.67.

9. THE SECOND LAW OF THERMO-DYNAMICS.—Let (32) be divided by $\frac{3}{2}v$ and multiplied by dv,

$$\therefore\ pdv+\tfrac{1}{3}\Sigma r\mathrm{R}\frac{dv}{v}=\tfrac{2}{3}ak\tau\frac{dv}{v}\ .\ .\ .\ (57).$$

But v varies as r^3,

$$\therefore\qquad v=cr^3\ \text{and}\ \frac{dv}{v}=\frac{3dr}{r}\ .\ .\ (58).$$

Substitute in the second term of (57)

$$\therefore\qquad pdv+\Sigma\mathrm{R}dr=\tfrac{2}{3}ak\tau\frac{dv}{v}\ .\ .\ (59).$$

which is a general equation due to Clausius,* holding for any variation of state of a permanent gas. The first member expresses the work done, the first term being that done against external forces and the second term that done against the intermolecular attractions. If these equations are to be applied to gases in which the molecules themselves occupy an appreciable fraction of the total in which they move, the effect of their mutual encounters can be taken into account by regarding the volume v not as the total space occupied by the unit of gas, but as the free space remaining after deducting that actually occupied by the molecules themselves. The space so occupied may be taken to be approximately that of the gas when condensed to a liquid state. Our formulæ may then be all rendered more exact by defining v to be this free space. If the increment of the total work done be denoted by dw, and if for compactness we put $dv\div v=dlogv$ (59) becomes

$$dw=\tfrac{2}{3}ak\tau dlogv\ .\ .\ .\ .\ (60).$$

If this general value of dw be substituted in the general equation (43), and the equation be then divided by τ, the result may be written in the form

$$\frac{dh}{\tau}=kd(log\tau+\tfrac{2}{3}alogv)\ .\ .\ .\ (61).$$

in which we have put for simplicity $d\tau\div\tau=log\tau$.

Since the last member of (61) is a perfect differential, (k and a being supposed to be constant) the first member of (61) is also a perfect differential, and if integrated the value of the integral will depend solely on the limits and not on the special path over which it is extended between those limits. This expresses, as is well known, the fundamental principle of the second law of thermo-dynamics.

* Phil. Mag. 1875, vol. 50, p. 195.

ERRATA AND CORRECTIONS IN THE FEB. NO. PAGE 123, ETC.

Page 123, column 1, line 35, for with, read and.
" 123, " 2, " 46, " Nilyer, read Meyer.
" 124, " 1, " 58, " one, read one which.
" 124, " 2, " 32, " to, read be.
" 125, " 1, eq. (4) " $x\times dt$, read $x\mathrm{X}dt$.
" 125, " 1, line 23, " square, read large.
" 125, " 2, eq. (6), " $x\mathrm{X}$, read $-x\mathrm{X}$, etc.
" 126, " 1, " (14), " v^3, read V^2.
" 126, " 2, line 11, " not, read not differ much
" 127, " 2, " 49, " Enler, read Euler.
" 128, " 1, " 46, " there, read then.
" 129, " 2, eq. (34), " k', read k.
" 130, " 2, line 12, read $d(pv)=0$.
" 130, " 2, eq. (38), for $\frac{1}{2}$, read $\frac{1}{2}f$.
" 131, " 1, " (40), " $vdp=$, read $vdp-$.

The paragraph commencing on page 130, column 2, line 23, and extending to line 10, page 131, column 1, goes on the supposition that the internal work depends upon terms other than those in $\mathrm{R}dr$, which is not the fact, those being the only ones expressing the work performed against the intermolecular attractions. The correct general equation to replace (39) will be obtained later. The same error vitiates the meaning of Art. 8. We shall, therefore, give a revised investigation of the ratio of the specific heats, after detailing some further considerations which show that $\mathrm{R}dr$ and $r\mathrm{d}\mathrm{R}$ are of opposite sign, and that the latter is always numerically the larger.

REPORTS OF ENGINEERING SOCIETIES.

ENGINEERS' CLUB OF PHILADELPHIA.—At the meeting of January 20th, Mr. Wm. E. Lockwood, presented a full description of the Shaw locomotive, profusely illustrated by magic lantern, working model, etc., etc.

The Shaw locomotive may be classed as a 37-ton soft-coal pas-enger engine, with two cylinders on each side, each 10½x24 inches: the two working in combination, being equivalent to one cylinder 14.85x24 inches; two crossheads; two piston rods; two connecting and parallel rods on each side.

Her drivers are 5 feet 9 inches; weight of engine, 67,000 pounds; coal and water, when in use, 73,000 pounds. Total, 74.300 pounds. Weight of tender, 26,000 pounds; water, 15,000 pounds; coal, 6,500 pounds. Total, 47,500. Total combined, ready for use, 121,800 pounds, or 60.45 tons.

The improvement in engines claimed in the Shaw locomotive are:

First.—No counter-balanced drivers; ergo, no hammer blows and no nosing around.

Second.—A single movement of valve with duplex action.

Third.—Steam is the motor of balance as applied to the reciprocating parts.

Mr. Wilfred Lewis exhibited a machine for the graphical determination of center of gravity and moment of inertia of plane areas. The figure to be calculated is drawn to a suitable scale and placed in the machine, where the outline is followed by a tracing point in order to produce, upon another piece of paper, a figure whose area shall be proportional to the statical

moment of the given figure about an assumed axis. If now the second figure be followed by the tracing point and a third figure be drawn, its area will be proportional to the moment of inertia; and from the areas thus drawn can be found, by simple arithmetical processes, the center of gravity and moment of inertia.

The machine is intended for application to such figures as cannot readily be solved by the usual methods, such as deck beams, steel rails, and castings, with round corners, large fillets and curved sides, which can only be approximately solved by long and tedious integrations. A planimeter is used to measure the areas and it is thought that by this graphical method, more accurate results can be obtained with less work and without so much probability of error in the operations. The machine can also be made use of to determine the contents of any solid of revolution or its radius by gyration.

Mr. Wilfred Lewis announced that Prof. Channing Whitaker, and a party of students of the Massachusetts Institute of Technology were about to visit Philadelphia. It was suggested that the use of our rooms be extended to them and an attendant employed during their visit, which suggestions met with the unanimous approval of the meeting.

February 3d.—Mr. W. S. Auchincloss exhibited and described his latest forms of Averaging Machine, which consists of an endless platform, the grooves of which represent days or distances. The various weights, representing quantities or values, are placed in these grooves and the endless platform rotated until a balance of the weights is secured, when the exact answer may be read from the accompanying scale and, by then continuing the rotation, the weights fall upon an inclined plane, reach their respective compartments in front, and are again ready for immediate use. The machine is of special interest to the engineering profession in its application to the location of engines, boilers and coal bunkers in steamers, the determination of diameters of pulleys, speed of shafting and average haul of material.

Mr. J. J. de Kinder described the United States Metallic Packing for piston rods, valve stems, pump rods and throttles—exhibiting sections and model; also model with packing it is intended to supersede. The metallic packing consists of eight composition blocks, held in a brass ring, on which are horns holding the springs which regulate the pressure of the block on the rod. It is said to preserve a steam tight joint without appreciable friction or binding. The vibration of the rod is provided for by a ball joint on one end and spring follower on the other, which contrivance is said to give the packing free play and preserve its tightness, notwithstanding a vibration of the rod.

The Secretary announced the sudden death of Mr. Wm. L. Billin, Member of the Club, and upon the motion of Mr. W. Bugbee Smith, the president, was requested to appoint a committee to prepare a memorial for publication in the proceedings.

ENGINEERING NOTES.

THE SUEZ CANAL.—The Works Committee of the Suez Canal Company has now decided upon the expenditure of about £920,000 on improving the canal and its dock accommodation. The first improvement consists in the construction of a siding or resting and passing place, 500 meters in length and 25 meters in width, along the sheltered slope northward from the Quai Eugénie, and the second is the construction of a new dock at Port Said, on the African bank of the canal and south of the Ismail dock. It is to be 750 meters long and 200 meters in width. The widening of the canal where it crosses the Bitter Lake, between Suez and the 152d kilometer station, already commenced, is to be pushed on to completion, so that the width will be 40 instead of 22 meters. The siding at Kantara is to be increased from 1,000 to 4,000 meters in length, while that at the 153d kilometer is to be increased from 700 to 2,000 meters in length, and increased from 26 meters on both sides, measuring from the center of the canal, to 40 meters on each side. The station at Lake Tamsah is to be doubled in area, and thus made to contain as many vessels as the Kantara siding. The curve at the north of El Guise is to be widened from 42 meters to 71½ meters, and other curves are to be similarly treated, to facilitate navigation. At Port Tewfik the siding accommodation is to be greatly enlarged, and the floating dock at the same place deepened. By these improvements, the execution of which is to extend over several years, the estimated traffic capacity will, it is expected, be doubled, or increased to 10 million tons. When the traffic reaches this the committee propose to take into consideration the idea, not the proposal, they say, of constructing a second canal parallel with that existing, so as to make up and down lines of traffic. If the English scheme for the Alexandria canal is carried, there will soon be a lot of work going on in this part of Egypt.

THE ANTWERP WATERWORKS.—At the eighth meeting of the Institution of Civil Engineers the paper on "The Antwerp Waterworks" was read by Mr. William Anderson, M. Inst. C. E.

The author commenced by stating that in 1879 the concession for the supply of water to the city of Antwerp fell into the hands of his firm. Antwerp had a population of 200,000 inhabitants; it ranked as the third largest port in Europe, and was being rapidly extended and embellished. Previous to the construction of the works the water supply was derived from shallow wells and open canals. As the sewage arrangements were very imperfect, the well water, though clear, bright and sparkling, was for the most part, dangerously contaminated. The scheme adopted by the author's firm, the only one practicable from a financial point of view, was originally suggested by Mr. J. Quick, M. Inst. C. E., and consisted in taking the waters of the river Nethe, an affluent of the Escaut, at a point eleven miles from Antwerp, where it was crossed by the Malines road. The waters of the Nethe were, however,

quite unfit to compete with the existing supply, after only ordinary filtration through sand, because they were greatly colored by peaty matter and very finely suspended mud, which could not be separated either by subsidence or filtration. Moreover, there would have been great risk in introducing into an important town water from a river which flowed through a highly cultivated and populous country; and the attempt to supply Antwerp from the Nethe would probably never have been made had not Professor Bischof's process of filtration through spongy iron come under the notice of the author. The properties of finely divided metallic iron as a material for filters had for some time attracted the attention of chemists. Professor Bischof, Dr. Frankland, and Mr. Hatton had demonstrated that it possessed the power of destroying organic impurities, removing color, separating finely-suspended matter, softening, and, above all, destroying the germs of putrefaction, of bacteria, and probably those of epidemic diseases. To confirm the evidence afforded by laboratory experiments, and by spongy iron domestic filters, which had been in use for some time, it was determined to carry out experiments on a large scale at Waelhem, the proposed site of the intake of the works, under the auspices of Mr. Ogston, Assoc. Inst. C. E. The arrangement recommended by Professor Bischof took the form of a pair of filters, having an aggregate area of 680 square feet. The first filter was to be placed on a higher level than the second, and to be filled with a bed of spongy iron and gravel, mixed in the proportion of one to three, covered by a layer of ordinary filter sand, the office of which was to separate the grosser suspended matter. In this filter the water would become charged with iron, to eliminate which it was to be exposed to the air, and passed through a second or ordinary sand filter, in which the red oxide would be deposited. The experiments were carried on for three months, and proved so satisfactory that all doubts about the efficacy of the process were removed, and the designs were made for the permanent works. The terms of the concession required a daily supply of 33 gallons per head for 175,000 inhabitants, or nearly six million gallons per day; but, in the first instance, the pumping machinery and main were to be laid down for only 40 per cent. of that quantity. The works consisted of a 42-in. intake pipe, two settling-ponds of an aggregate capacity of 2,640,000 gallons, a pair of Airy's screw-pumps, worked each by an independent engine, for raising the settled water 19 feet into the spongy iron filter beds; three spongy iron filters having an aggregate area of more than 31,000 square feet; three sand filters of the same area; two cast-iron filtered water tanks, containing together 340,000 gallons, and two pairs of beam pumping engines of 170 horse-power each, together with their boilers and fittings. The Nethe being a tidal river, carrying up the drainage of Malines on the flood and bringing down that of the villages on its upper waters on the ebb, the authorities prescribed certain limits within which alone the water should be taken. These restricted the time available for filling the settling ponds to about three quarters of an hour in each tide. The settling points, of a capacity to hold twelve hours' supply, were excavated immediately in the rear of the river bank and lined with dry stone pitching. The nature of the ground was exceedingly treacherous, a bed of water-logged silt extending under the whole area, at a depth of 6 feet to 7 feet below the surface. It was thought prudent, therefore, to construct the filter beds entirely of earthwork resting on the surface, and to trust to puddle linings to secure the necessary water-tightness, and to adopt pile foundations for the engine-house and chimney. The environs of Antwerp, being very flat, did not permit of a high-service reservoir being constructed. The filtered water tanks were, therefore, placed close to the engine-house, and the service was maintained by uninterrupted running of the engines, which, for this purpose, were arranged in pairs, each pair coupled at right angles, so that they could run at any speed between 1½ and 22 revolutions per minute. To provide against the effect of frost, the novel expedient was adopted of heating the water, as it flowed to the screw-pumps, by means of injected steam, the author stating that the experience of last winter seemed to indicate that the arrangement would prove efficient. The result of eighteen months' working had been very satisfactory, the water having remained pure, bright and clear throughout the time. The spongy iron had not shown any signs of deterioration or wasting; and Dr. Frankland, who had visited the works, had reported very favorably of the process employed, not only with respect to the chemical condition of the water, but also with reference to the complete destruction of bacteria and their germs. The water from the pumping-station was carried in a 20-in. main for ten miles along the Malines road; its course was described at length, together with the appliances for getting rid of air and of avoiding dangerous shocks. The distribution of subsidiary mains and service pipes in the city was explained, together with the manner in which the various services were laid on. By the system adopted a constant circulation was kept up, as far as possible, in the distribution pipes throughout the city. It permitted a range of pipes to be shut off without stopping the supply of the neighboring streets, and even often enabled the service to be kept up when portions of one of the mains had to be shut off. A comparison was instituted as to the relative cost of German and English pipes. The manner of testing, as fast as the pipes were laid, was described, and the paper concluded with the statement that the works were erected in fifteen months, at a cost of £280,000.

EXCAVATING WET MATERIAL BY HYDRAULIC PROCESS.—By J. T. Dodge, Member of the Western Society of Engineers. Read Dec. 5, 1882.

In constructing the "East Approach" of Bozeman Tunnel, which is about 550 feet long from the mouth of the cut to the portal of the tunnel, an unusual amount of wet and sliding clay was encountered.

The first 200 feet of the cut being dry was

excavated without difficulty. In the next 200 feet springs were encountered, and heavy slides occurred, amounting to three or four thousand yards. This material, tough and adhesive, and saturated with water, was extremely difficult of removal. Shovels had to be dipped in water to make it slide off. Water had to be put on the cars to make it slide out, and when once started on a slide it was not disposed to stop, but went from fifty to one hundred feet beyond the limits of the embankment.

The work was begun in February last and was prosecuted with as much diligence as the unfavorable season would allow. By the 15th of July the contractor and all immediately connected with the work had become very much discouraged. The division engineer was applied to for advice and direction.

Timbers had been tried and swept away by the resistless "mud glacier." Driving piles was suggested as a means of holding back the mass. Tunneling through it was seriously considered. To go on with the work as it had been going on seemed hopeless.

"Sluicing" had been thought of when the work was first commenced, but there did not appear to be a sufficient supply of water within a reasonable distance. The placer mines of Helena being still in process of working, the writer availed himself of the opportunity of examining their methods of using water in the removal of earth.

After doing so, and after having an interview with the principal owner, a gentleman of long experience in hydraulic mining, a survey was ordered, and it was ascertained that by digging a ditch three miles long we could reach a creek two miles west of the Summit, which gauged 250 miners' inches, and which would probably supply water enough to remove 500 yards of earth per day.

It was then decided that if the contractor would surrender that part of the work, the railroad company would try the experiment of "sluicing."

Accordingly, the ditch was commenced on the 20th of July and completed on the 9th of August, so that water commenced running through the cut on the latter date.

The grade of the ditch was assumed at 13.2 feet per mile, and its area at about 4 feet. Several flumes had to be constructed across narrow ravines, and some rock cutting was encountered. A "ground sluice" 2 feet wide by 11 inches deep was placed in one side of the cut, on a grade of 2 2 feet per 100, parallel to the grade of the railroad. Water for the jet was taken from the main ditch in a flume 11 by 12 inches, and conveyed by about 300 feet of 6-inch galvanized iron pipe and 112 feet of cotton hose, down into the cut, where it could be operated under a head of 60 feet. The nozzle was provided with one 2-inch ring and one 1¾-inch ring, to be used as circumstances might require. To supply this nozzle probably required about 40 inches of water when under 60 feet head.

The 1¾ jet was more compact and effective in cutting down tough and hard banks than a 2-inch jet.

The whole amount of water reaching the work during the first few days of our operations probably varied from 120 to 150 inches. The weather being dry and hot, it began to diminish soon after, and fell as low as 72 inches about the 10th of September. The weather then turning cooler, it increased to a moderate extent, and then remained about the same till work was completed on the 24th of September.

By a careful estimate of the work done in the first twelve days, it appears that the amount of earth moved was 727 yards per day.

The amount done between the 10th of August and the 24th of September was 17,060 cubic yards.

The cost of moving the same, including digging the ditch, buying pipe and hose, and all other expenses, was less than 30 cents per yard, which was far below what it would have cost by shoveling.

The work was prosecuted night and day by three shifts of two men each. Near the close of the work, a few men were employed in daytime in sloping, and some labor was used in making a dam to save part of the material in embankment.

The delay of the work during the time the ditch was being dug was probably a benefit, by giving the ground time to dry and drain out, so that no large slide occurred after "sluicing" was commenced.

The amount of earth moved between the 1st of February and the 20th of July, by shoveling at the bottom and scraping from the top, was 19,730 cubic yards, an amount which could have been removed in twenty-seven days by sluicing with the volume of water used during the first twelve days.

IRON AND STEEL NOTES.

OUR PRODUCTION OF BESSEMER STEEL IN 1882.—We have received complete statistical reports from the companies owning the fourteen completed Bessemer steel works which were in operation in the United States during the year 1882. From these reports we learn that the quantity of Bessemer steel ingots produced in the United States last year was 1,696,450 net tons, or 1,514,687 gross tons. The increase over the production of 1881 was 10 per cent. This is a much smaller annual rate of increase than has been made for several years. The increase in the production of 1881 over that of 1880 was 28 per cent., while 1880 increased 30 per cent. over 1879. The production of Bessemer steel ingots in the last six years has been as follows, in net tons:

1877	560,587	1880	1,203,173
1878	732,226	1881	1,539,157
1879	928,972	1882	1,696,450

The quantity of Bessemer steel rails produced in 1882 by the fourteen works above referred to was 1,334,349 tons, or 1,191,383 gross tons. This was an increase of 6 per cent. on the production of the same works in 1881, which amounted to 1,253,129 net tons, or 1,118,865 gross tons.

These figures do not cover the total produc-

tion of steel rails in the United States, as there were some rails rolled in 1882 from imported steel blooms, and there were also some open-hearth steel rails rolled. Complete statistics of the production of these kinds of rails, however, have not yet been received. They will probably not quite reach 100,000 gross tons, making our total steel-rail production in 1882 approximate 1,300,000 gross tons, against a total in 1881 of 1,210,285 gross tons.

The fourteen Bessemer steel works referred to above contain thirty-five converters. The Scranton Steel Company is building a 2-converter plant at Scranton, Pennsylvania, which it is expected will be completed and will be put in operation in the spring.—*Bulletin.*

A Singular Case of Corrosion of Steel. By Prof. Chas. E. Munroe, U. S. N. A.—Through the kindness of Chief Engineer Farmer, my attention has recently been called to the appearance of two cold chisels found in the U. S. S. "Triana" in 1874, and which have since been preserved in the Department of Steam Engineering at the Naval Academy. These chisels were taken from the channelway leading from the jet condenser, and they were located between the foot valve and the air pump. Both chisels were of steel throughout, as was proved by tempering the head. For use, of course, only the points had been tempered. During the time of exposure to the action of the salt water in the channelway the chisels were deeply corroded, but the corrosion was confined entirely to the soft metal, the tempered points not being attacked in the least. The corrosion was deepest at the line of contact between the tempered points and the untempered metal of the haft. The line of immersion, on tempering, is as distinctly marked as if drawn with a shading pen. Since meeting with these chisels I have heard of a similar case of corrosion, although the object has been lost. It was a hammer which had been taken from the boiler of a merchant steamer, the tempered faces of which were intact, while the soft metal was corroded.

Remembering the heated discussion going on in metallurgical circles on the question "What is Steel?" I shall not attempt to decide whether the change which takes place in the tempering of steel is a chemical or a physical one; but it is evident that this change produces a body which is not so readily acted upon by salt water as untempered steel is. It is also probable that when the untempered and tempered steels are brought in contact in the presence of salt water we have an electro-chemical couple, and that this hastens the destruction of the untempered metal. I beg to suggest that this observation may have a practical bearing upon the construction of steel ships.—*Proc. U. S. Naval Institute, No.* 21.

RAILWAY NOTES.

Railways of the World.—An article by M. Paul Trasenster, of the Government School of Mines, at Liege, tracing the growth of the railway system of the world, is quoted from the *Revue Universelle des Mines* in *The Economist.* Starting with the year 1840, when railway construction was in its infancy, M. Trasenster shows how the 5,000 miles of line then in operation have grown into a total of nearly 250,000 miles, and how the system, which was then practically confined to a few European countries and the United States, has now spread to all quarters of the globe. In the subjoined table the progress of the development is shown in detail, and it may be summarized thus:

Length of Lines in Operation on the 31st December.

	Europe.	America.	Asia.	Australasia.	Africa.	Total.
	Mls.	Mls.	Mls.	Mls.	Mls.	Mls.
1881.	108,002	122,186	10,774	5,481	3,147	249,590
1880.	105,429	109,521	9,948	4,889	2,904	232,691
1879.	103,237	101,196	9,269	4,363	2,705	220,770
1875.	89,323	84,648	7,072	2,312	1,552	184,907
1870.	64,667	58,848	5,118	1,042	956	130,631
1860.	32,354	33,547	844	350	298	67,393
1850.	14,551	9,604	..	..	..	24,155
1840.	2,131	2,859	..	..	..	4,990

The rate of progression, it will be observed, has been rapid, and on the whole, continuous. There has not, of course, been an equal development each year. In years of prosperous trade and active speculation the work of construction has been pushed on with great energy, while in times of depression it has languished.

Between 1870 and 1881, the year of least activity was 1878, the length of new line opened in that year being slightly under 8,000 miles; while, on the other hand, the year 1881 was one of exceptional activity, no fewer than 15,100 miles of new lines—that being the largest total ever recorded—having been added to the various systems. Passing from the record of the past to the prospects of the future, M. Trasenster takes a survey of the condition of the various countries in which the work of railway construction is being carried on.

On the whole, the probability seems to be, that in the immediate future the railway systems of the world will be developed with much greater rapidity than has yet been attained, and M. Trasenster estimates that the increase in 1883 is not unlikely to be as much as 17,000 miles. Whether such a rapid growth can long be sustained is another question.

Railway Growth in America.—The past year has undoubtedly been the most remarkable in the railroad growth of the north-west States of America, as it has been the most remarkable in the railroad development of the United States. Nearly all the construction in the north-west is legitimate, in the sense that its object is the development of the country, and that the enterprises promise solid

returns upon the investment. The aggregate of new mileage in this territory, in which St. Paul and Minneapolis are directly interested, is 2,400. The Northern Pacific comes first, with 870 miles newly constructed on all its divisions. The energy with which construction has been pushed on this line is phenomenal, and promises the easy completion of the entire transcontinental trunk before the end of 1883. Then will begin the construction of the lateral lines, north and south from the main line, carrying on laterally the development now confined to a narrow belt along the main line. The St. Paul, Minneapolis, and Manitoba line cannot show, like the Northern Pacific, a long stretch of new trunk line, but it outdoes the other road in the rapidity with which it is gridironing their joint territory in Northern Dakota. With branches and feeders, the total extensions of the Manitoba road in 1882 amounted to 221 miles, of which more than half is in the Devil's Lake and Turtle Mountain country. The agreement between these two companies for an amicable division of territory promises energetic joint action next year in filling gaps and advancing the material growth of Northern Minnesota and Dakota. The North-Western has increased its total mileage in 1882 469 miles, of which 129 miles are in Dakota and 100 miles in Iowa. Perhaps the most significant construction is the north and south branch in the James River valley, which is initiated by the Milwaukee road running north from Millbank. The largest actual construction of the Milwaukee road has been in Iowa. On the division which gives the Milwaukee access to Council Bluffs 263 miles have been built. The next most important construction is the branch from Wabash up to Chippeway and the Valley line, 75 and 32 miles respectively.

MR. BRUNLEES in his address before the Institution of Civil Engineers, briefly referred to the want of railway communication in many productive countries. The immense population of China would derive great advantages from the construction of railways. It had been said that the objection of the Chinese proceeded chiefly from the fear of introducing foreigners in any considerable number. Chinese statesmen, even those most liberal and enlightened, at one time believed that railways were not adapted to the circumstances of China. They had recently formed a different opinion. An official memorial had been drawn up by one important Government officer, and favorably reported on to the Government by another high official, suggesting and recommending the construction of four important trunk lines, and no doubt if these were once executed many more would follow. In India somewhat more than 900 miles of railway were in course of construction, including three bridges of more than ordinary importance. When the works now in progress were completed, India would have nearly 12,000 miles of railway open for traffic. In New Zealand the length of railway in various stages of progress during the year ended 31st March last was 234 miles, and 1,333 miles were then open for traffic, and an additional expenditure of £1,650,000 had been ordered. In Queensland only a few miles appeared to be under construction; but an extensive system of railways was under the consideration of the Government. In South Australia considerable progress had been made in railway building, and this might also be said of Victoria and New South Wales, where there were 342 miles under construction. He regretted that the Australian colonies had not adopted the same gauge for their lines. With the disadvantages which had arisen in England, in India, and in America, from a break of gauge, and from the great advantages which Western and Central Europe had derived from a uniform gauge, it might have been thought prudent on the part of the Australian Colonies to have accepted the experience of older communities. In Canada, 2,910 miles of railway were under construction; and in the United States some 11,000 miles had been constructed during the last year. In the United States and in Canada the tendency was towards a uniformity of gauge.

ORDNANCE AND NAVAL.

A NEW IRONCLAD.—In accordance with Admiralty instructions, preparations are being made at Chatham Dockyard for the construction of another large armor-plated ship, to be named the *Mersey*. She will be over 300 feet long, and about 40 wide. Her engines will be very powerful.

LOCOMOTIVE TORPEDOES FOR COAST DEFENCE.—The session of the Royal United Service Institution, Whitehall Yard, was opened on January 19 with a lecture by Lieutenant C. Sleeman, R. N.—Admiral Boys presiding—on "Locomotive Torpedoes." The lecturer divided the submarine weapons known as locomotive torpedoes, carrying within themselves the power of locomotion, into two classes—first, the uncontrollable (those which cannot be controlled at the will of an operator); and second, the controllable (those capable of being directed by the operator). In the uncontrollable class he placed the Whitehead fish torpedo, and he held that this was the most perfect torpedo of its class. The advantage of this weapon was that up to its limit of accurate range, 500 yards, it was entirely self-acting, and the vessel using it had nothing further to do with it when once it was discharged. Moreover, it had great speed, covering the 500 yards in 40 seconds. Its disadvantages were its limited accurate range, the complicated nature of its adjustments, and the necessity of discharging it from special apparatus. He mentioned that the German government had been making experiments with sunken batteries, containing several Whitehead torpedoes, discharged from the battery by electrical means under the control of those on the shore batteries, with the purpose of increasing the range of this torpedo; but he did no know what success had attended the experiment. He then dealt with the second class, the controllable, and described the Ericsson, the Brennan, and the Lay, the last men-

tioned the invention of Colonel Lay. The first, he said, had been under trial in America, but the trials were not regarded as successful. The Brennan was an Australian invention, and had lately been under experiment at Chatham. This he described as a weapon moved ahead and steered entirely by mechanical means, those means being the connecting of the shaft of two drums placed in the body of the torpedo. These are made to revolve by fine wire reeled on them and connected with the directing point. The steering is effected by increasing or decreasing the velocity of either of the reels at the directing point. At Chatham a speed of 14 knots an hour was attained, and the weapon was controllable up to about 1,200 yards. The lecturer considered that the disadvantages of the weapon were many, while its advantages were few. The Lay then came under notice, and this was illustrated by diagrams. The weapon, which had been successfully experimented with in Russia and Belgium, was the only existing type of its class. It was constructed of steel, one-eighth of an inch in thickness, and was divided into three distinct sections—first, the bow section; second, a reservoir section, with the motive power, carbonic acid gas; and third, the after section, containing the steering apparatus. The total length of the whole was 26 feet, its maximum diameter 24 inches, and it weighed when completely loaded, one and a half ton. The amount of explosive carried in one type of the Lay was 90lbs. of dynamite, while the Russians had increased the charge to 150lbs. of that explosive. The charge could be exploded at will, or by contact. The lecturer described the controllable character of the Lay for its run of a mile and a half for harbor defence, or of three quarters of a mile to a mile when used against a ship. He dwelt upon the value of this torpedo in harbor defence, and he held that the ingenious Nordenfelt sub-marine boat, armed with two of the Lay torpedoes, would make the most successful attack on a harbor most doubtful. He also graphically and clearly described the Lay torpedo in ship attack and defence, and the advantages which a ship possessing the Lay would possess over a better armed vessel without this torpedo. He also pointed out the circumstances under which this torpedo would prove a most valuable factor in the defence of rivers, estuaries, and channels. Admiral Gore Jones, who opened the discussion, dwelt upon the inconvenience and danger arising in the Lay torpedo from the motive power arising from carbonic acid gas in the reservoir, and he stated that in the earlier experiments, the cable kinked, and the experiments had to end. He contended that the use of the torpedo could only be limited. Colonel Gallway, R. E., dwelt upon the danger in a ship of carrying dynamite for the arming of the Lay, and he questioned whether in practice in sea battles the Lay would have all the advantages claimed for it. Captain M'Clear, R. N., offered some ob-ervations, and then Mr. Nordenfelt answered some of the objections started by Admiral Gore Jones. Captain Crozier and other speakers took part in the discussion, which closed after the lecturer had replied, with a vote of thanks to that officer.

BOOK NOTICES

PUBLICATIONS RECEIVED.

FOURTEENTH ANNUAL REPORT OF THE MASSACHUSETTS BOARD OF RAILROAD COMMISSIONERS.

MONTHLY WEATHER REVIEW FOR DECEMBER. Washington: Gov't Printing Office.

THE NAVAL USE OF THE DYNAMO-MACHINE AND ELECTRIC LIGHT. By Lieut. Murdock, U. S. N.

PRIMARY TRIANGULATION OF THE UNITED STATES LAKE SURVEY. By Lieut.-Col. Comstock, Corps of Engineers. Washington: Gov't Printing Office.

A TREATISE ON THE DISTILLATION OF COAL TAR AND AMMONIACAL LIQUOR. By George Lunge, F. C. S. London: John Van Voorst.

This purely technical treatise describes with great minuteness the processes and machines employed in the separation of the coal-tar products.

Chapter I. is devoted to the origin and nature of Coal Tar. Chapter II. deals with the chemical constitution of Coal Tar and the properties of the constituents. Chapter III. Applications of Coal Tar without Distillation. Chapter IV. The First Distillation of Coal Tar. Chapter V. Pitch. Chapter VI. Anthracene Oil. Chapter VII. Creosote Oil. Chapter VIII. Carbolic Acid and Naphthalene. Chapter IX. Light Oil and First Runnings. Chapter X. Rectification by Steam. Chapter XI. Ammoniacal Liquor

Free use has been made throughout of pictorial illustrations, and the printing is excellent.

SUGAR GROWING AND REFINING. By Chas. G. Warnford Lock, F. L. S.; G. W. Wigner, F. C. S., and R. H. Harland, F. C. S. London and New York: E. & F. N. Spon. Price, $12.00.

The topics treated in this voluminous treatise are in their order as follows:

Chap. I. Cultivation of the Plant (cane).
II. Composition of the Juice.
III. Extraction of the Juice.
IV. Defecation and Clarification.
V. Concentration and Granulation.
VI. and VII. Curing the Sugar: The Factory.
VIII. Cultivation of the Beet.
IX., X. and XI. Extracting, Defecating and Concentrating the Juice.
XII. Curing the Sugar.
XIII. to XVIII. Maple, Melon, Milk Palm and Sorghum Sugars.
XIX. Sugar Refining.
XX. to XXIV. Factories, Statistics, Analysis and Distillation of Rum.

Ten plates and two hundred and five excellent engravings illustrate the text.

THE HEAVENS ABOVE. By J. A. Gillet and W. J. Rolfe. New York: Potter, Ainsworth & Co. Price $2.00.

A new impulse has been given to the study of astronomy by the celestial phenomena of the

past few years, and a new issue of elementary works is the natural result.

It is doubtless true that a liberal display of diagrams aids the learner in this department quite as much as in any other department of science.

The new book before us is abundantly supplied with well-selected illustrations, and is the most attractive looking school-book we have seen this season. More than the usual amount of space is given to stellar astronomy and rather less than the usual amount to the planets.

ELECTRO-MAGNETS. THE ELEMENTS OF THEIR CONSTRUCTION. Translated from the French of Du Moncel. Science Series No. 64. New York: D. Van Nostrand. Price 50 cents.

The thoroughly practical character of this latest addition to the Science Series, no less than the fame of the original author, will recommend this little manual to amateur scientists, as well as practical electricians.

The deductions of Du Moncel are chiefly based upon patient and skillful experiments. The well known formulas have been severely tested, and the limits of their applicability are duly stablished.

The mathematical investigations are such as the student of ordinary algebra can follow, and the principles finally deduced are so emphasized as to give them a special prominence.

Indeed, the laws, which are concisely formulated and italicized, would, if gathered together, present in a few pages a summary of all the principles necessary to guide the constructor to the making of electro-magnets according to the best known plans, whatever the use for which they are designed.

MISCELLANEOUS.

INTERNATIONAL ELECTRIC EXHIBITION OF VIENNA, 1883.—Among the many companies and societies now existing for the propagation of Electrotechnic science and its applications, the Society of Telegraph Engineers and Electricians is the oldest.

They count among their members not only the most eminent European names famous for scientific knowledge but also well-known in practice. Sir William Thomson, Messrs. Siemens, Preece, Col. Webber, Fleeming-Jenkins, W. Smith, Carey Foster, are among the number. This society has formed an Executive Committee for the special purpose of considering all affairs respecting the International Exhibition in Vienna. They will send the invitations and collect the applications of all English firms interested. There is no doubt, that interest in the exhibition will be much enlivened by the efforts of this distinguished party.

SOME time ago, the *Engineering Review* says, "A Philadelphia machinist devised a substitute for the resin or lead with which it is customary to fill copper pipes in order to bend them without buckling. This consisted of a close-wound square steel coil forming a mandril. To remove the mandril after the pipe was bent, it was only necessary to pull on one end, at the same time giving it a slight twist to lessen its diameter. At the time it was brought out it was said to do well, but nothing has recently been heard of it." Lead or resin meet the requirements for any size of pipe, while a large number of mandrils would be necessary. Perhaps this explains it.

IN chloride of sodium and chloride of potassium solutions, with access of cold air and carbonic acid, copper, brass, German silver and zinc, are violently attacked, while in the absence of carbonic acid, they undergo comparatively little change. The contrary is the case with lead, tin, and Britannia ware, these being attacked more violently when exposed to air free from carbonic acid than in air and carbonic acid. In the latter case, lead is only half as much affected as in former, tin not at all, and Britannia metal very little. In the course of experiments by Professor Wagner, with access of air free from carbonic acid, not a trace of any of the metals was dissolved; with access of air and carbonic acid, considerable quantities of copper, brass, German silver, zinc, and lead were converted into soluble compounds, only a trace of Britannia metal went into solution, and no tin was dissolved.

ALUMINIUM.—The experiments of Prof. Kennedy of London University show that the weight of a cubic inch is .0972 lbs., showing a specific gravity of 2688, and that its ultimate tensile strength is about 12 tons per square inch. The range of elasticity is large, the extension at the yielding point being $\frac{1}{100}$ part of its length. The modulus of elasticity is 10,000. The ductility of samples, 2 inches long, was only 2.5 per cent.; but it is probable that the metal could be improved in this respect.

Taking the tensile strength of this metal, in relation to its weight, it shows a high mechanical value. Its characteristics in this respect, as compared with those of other well-known metals, are shown in the following summary:

	Weight of a cubic foot in lbs.	Tensile strength per square inch, in lbs.	Length of a bar which is just capable of bearing its own weight.
			Feet lineal.
Cast iron.....	444	16,500	5,351
Bronze.....	525	36,000	9,893
Wrought iron...	480	50,000	15,000
Steel of 35 tons per inch....	490	78,000	23,040
Aluminium.....	168	26,880	23,040

It thus appears that, taking the strength of aluminium in relation to its weight, it possesses a mechanical value about equal to steel of 35 tons per inch.

Aluminium is, unfortunately, a very expensive metal, and although an increased de-

mand might lead to a considerable reduction in price, yet the process by which it is extracted leaves little hope at present of obtaining it at a rate sufficiently low for general use. But its mechanical properties point to its suitability for those cases where strength, combined with lightness and a great range of elastic action, are required. The elastic range is about three times that of steel, and about five times that of wrought iron. The discovery of a cheap process of extraction has just been announced.

SEVERAL of the trunk lines on the continent have been giving special attention to the establishment of rapid train services between important points for the accommodation of through travelers. A more or less important saving of time is expected to be obtained when the working arrangements are fully completed. According to the *Hamburger Nachrichten* the general arrangements of the "lightning express," which it is proposed to run from Ostend to St. Petersburg (*via* Aix la Chapelle, Dusseldorf, Berlin and Konigsberg), will correspond in every way with those of the train of the same description between Paris and Vienna. The halts will be few, and will only be for such lengths of time as the railway service requirements render indispensable. All the meals for passengers will be served in the dining-room of the train while in motion, and the arrangements for turning the saloons into sleeping cars are very complete. There is a gangway between each carriage, and the staff of attendants is to be sufficiently numerous to ensure the comfort of the travelers in every respect.

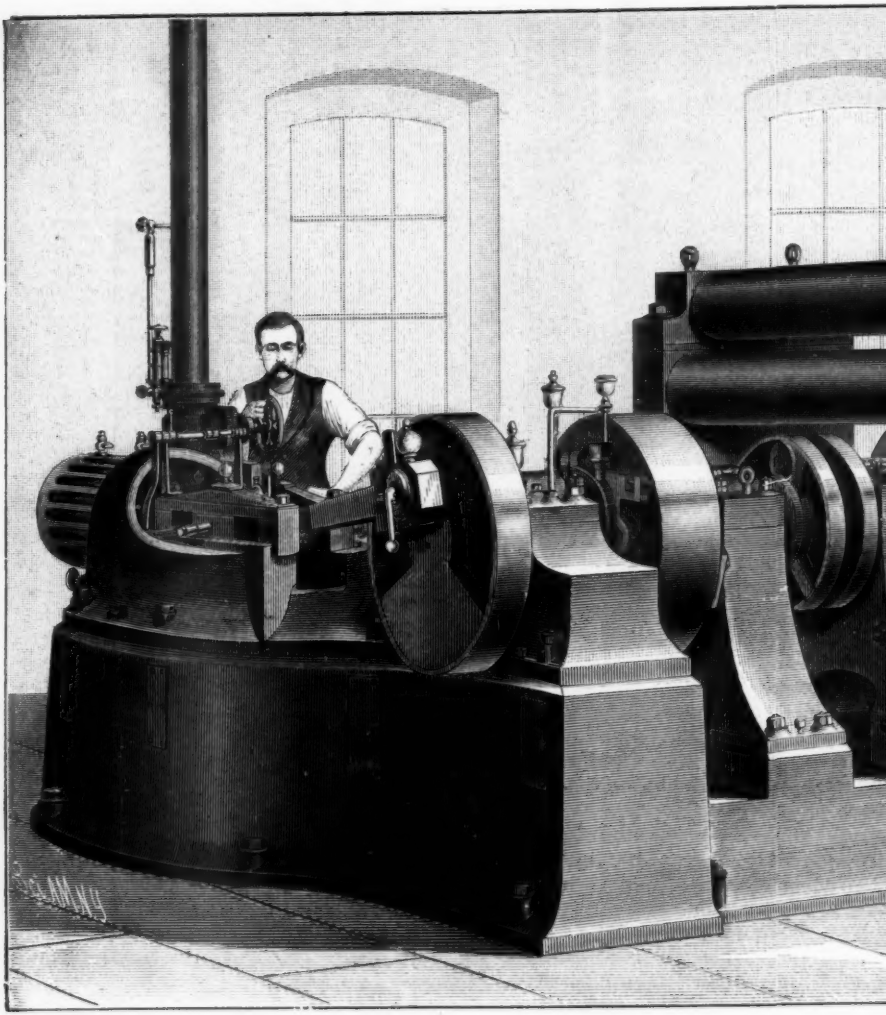
THE British Association Committee on underground temperatures in their last report adopt 64 ft. per degree rise in temperature, or 0.01566 of a degree per foot depth. To obtain an approximation to the rate at which heat escapes annually from the earth, they reduce the above rate of increase .01566 to Centigrade degrees per centimeter of depth. For this purpose we must multiply by .0182, giving .000285. To calculate the rate of escape of heat, this must be multiplied by the conductivity. Prof. Herschel, in conjunction with a Committee of the British Association, has made a very extensive and valuable series of direct measurements of the conductivities of a great variety of rocks, and has given additional certainty to his results by selecting as two of the subjects of his experiments the Calton Hill Trap and Craigleith sandstone, to which Sir William Thomson's determinations apply. From combining Prof. Herschel's determinations with those of Sir William Thomson, .0058 is adopted as the mean conductivity of the outer crust of the earth. which, being multiplied by the mean rate of increase, .000285 gives the flow of heat in a second across a square centimeter. Multiplying by the number of seconds in a year, which is approximately 31½ millions, we have $1633 \times 315 \times 10^{-4} = 41.4$. This, then, is the British Association Committee's estimate of the average number of gramme degrees of heat that escape annually through each square centimeter of a horizontal section of the earth's substance.

AT the opening meeting of the winter session of the Society of Arts on Wednesday evening, Dr. C. W. Siemens delivered an address in which he dwelt at considerable length on the present and probable future position and cost of electric lighting, and gave information leading to the conclusion that the progress of electric lighting had been greatly checked by that parasite, the promoter, that electric companies, even those promoted for work and not speculation, afford doubtful investment to present shareholders, that electric lighting can be accomplished at a less cost per year than gas, but that the plant will cost more.

A PATENT has been granted to Herr Beck, of Nordhausen, Germany, for a machine of which the motive force is supplied by gunpowder. In a horizontal cylinder a piston is set in motion by small quantities of powder, which are alternately ignited before and behind it. The gases which have been used escape through lateral openings closed by side valves at the return movement of the piston. The heavy residuum accumulates in the deepest part of the cylinder, and is pushed by the piston into receptacles which are emptied from time to time. The ignition of the gunpowder is effected by a spirit flame or by a gas jet, which is brought to bear upon it by the sucking action of the piston, through an opening provided with a side valve. A Cologne firm of engineers has, according to the *Deutsche Industrie Zeitung*, undertaken the construction of this machine, with a view to its being introduced for sale during this autumn. Amongst the advantages claimed for it is the comparatively small space it takes up, and the fact of its being constantly ready for use. The consumption of powder is relatively small, and no special attendance is required, as the machine is self-regulating.

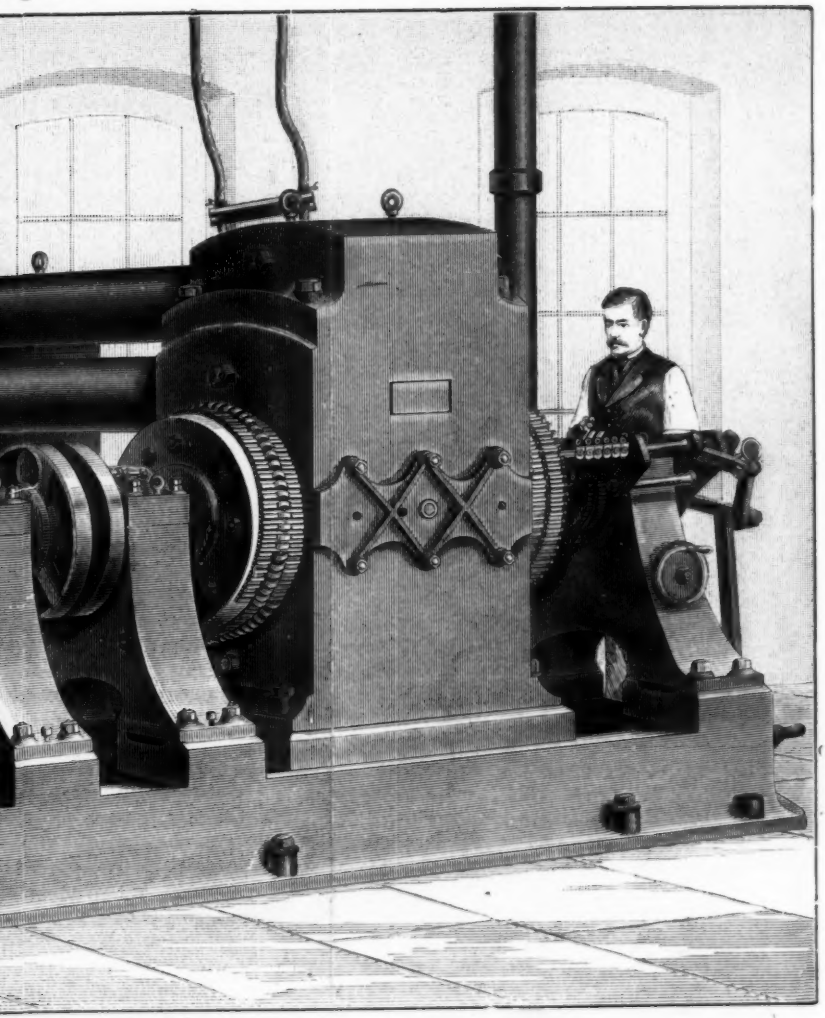
AN interesting article on Lavoisier, Priestley, and the discovery of Oxygen, by G. F. Rodwell, in *Nature* contains the following:—"Now what are the facts in favor of Lavoisier? On November 1st, 1772, he deposited with the secretary of the Academy a note, which was opened on May 1st following, in which he stated that he had discovered that sulphur and phosphorus, instead of losing weight when burnt, actually gained it, without taking into account the humidity of the atmosphere. He traced this to the fixation of air during the combustion, and surmised that the gain of weight by metals during calcination was due to the same cause. He reduced litharge in close vessels 'avec l'appareil de Hales,' and observed the disengagement of a great quantity of air. 'This note leaves no doubt,' says Dr. Thompson, 'that Lavoisier had conceived his theory, and confirmed it by experiment, at least as early as November, 1772.' . . . 'Il est aisé de voir, writes Lavoisier, just before his death, 'que j'avais conçu, dés 1772, tout l'ensemble du système que j'ai publié depuis sur le combustion.'" This date is apparently more than a year before Priestley discovered it without knowing it.

Fig 30.



EDISON'S STEAM

Fig 30.



TEAM DYNAMO.